

Pastoralists' Socioecological Trends: The Case of Laikipia County in Kenya

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Abstract

Pastoralism is a complete way of life involving ecological, political, economic and social dimensions, and is dependent on a continuous balance of diverse factors. However, pastoral systems are faced with emerging and accelerating shocks and stresses that challenge their resilience and the ability to meet household livelihood needs sustainably. In response to these pressures, pastoralist socioecological systems in Africa are undergoing a process of rapid transformation that is marked by positive and negative socio-ecological trends. This study, therefore, analyzed the socioecological trends of pastoral systems with a focus on Laikipia County, Kenya. The study used a participatory action research design and multi-stage sampling design. Data collection and analysis were done using the participatory trend analysis method, while Mann-Kendall Z Test and Kendall's correlation coefficient were used to test the trends and their relationships. This study finds that pastoralists' culture and lifestyles are changing as shown by the negative trend in observation of cultural practices ($Z = -4.22, P < 0.001$) and effectiveness of customary governance systems ($Z = -0.401, P < 0.001$). Secondly, although the total number of livestock is increasing ($Z = 3.11, P < 0.01$), there is a downward trend in the livestock holding per household ($Z = -3.83, P < 0.001$), and, hence increasing diversification to non-pastoral livelihoods ($Z = 4.28, P < 0.001$). These changes are caused by the growing pressure on pastoral resources and ecological stresses due to various factors, including the increasing human population ($Z = 4.22, P < 0.001$), land degradation ($Z = 4.17, P < 0.001$), and climate change and variability ($Z = 4.05, P < 0.001$). Therefore, the study enabled an understanding of pastoralists' socioecological trends and the underlying drivers. Moreover, the study showed the impacts of the drivers, their feedback on each other, and the responses of the pastoral system. The study will strengthen pastoral development planning and policy-making processes.

Keywords

Pastoralist; Trend; Livelihood; Livestock; Resources

Introduction

Pastoralism is a complete way of life involving ecological, political, economic and social dimensions, and is dependent on a continuous balance of diverse factors (FSAU, 2001). Pastoral livelihood systems are, thus, able to deal with a delicate balance of

factors, which make them relatively resilient to temporary shocks and stresses (FSAU, 2001). However, pastoral systems are faced with emerging and accelerating political, economic, social, political, ecological and climate shocks and stresses that challenge their resilience and ability to adapt (Dong *et al.*, 2011; Turner, 2011; Reid, Fernandez-Gimenez and Galvin, 2014).

Therefore, many pastoral systems are failing to meet households' livelihood needs and sustainably managing the natural resource base (Kaye-Zwiebel and King, 2014). This is evidenced by several studies that observed that pastoralism is increasingly becoming vulnerable to the effects of climate change and variability (Ouma *et al.*, 2018). In addition, although pastoralists' socioecological systems have historically been very resilient, recently there has been a trend of an increasing frequency and magnitude of sudden livestock production losses (Cottrell *et al.*, 2015).

In Sub-Saharan Africa, such breakdowns in resilience are a complex legacy of the last century (Kaye-Zwiebel and King, 2014). Colonization, nation formation, population growth, social and economic modernization, and the imposition of statutory land tenure systems have frequently impinged on the pastoralist's way of life (Kaye-Zwiebel and King, 2014). These factors have tended to decrease pastoralists' capacity for customary governance and grazing management, and to restrict the traditional strategies for coping with disturbances such as drought (Fratkin, 2001; Catley, Lind and Scoones, 2013). Besides, the sustainable management of pastoralism in many countries has been impeded by the political, social and economic marginalization of pastoralists (Davies *et al.*, 2010; Wynants *et al.*, 2019). This marginalization has resulted in chronic under-investment and under-development in pastoralist communities, inappropriate plans and policies, the resultant constraints on pastoralism growth and viability, and an increase in vulnerability (Kirkbride, 2008; Davies *et al.*, 2010).

Pastoralists are, thus, facing more pressure on their way of life than ever before (Fratkin and Mearns, 2003). In response to these pressures, pastoralists' socioecological systems in Africa are undergoing a process of rapid transformation (Galvin, 2009; Korf, Hagmann and Emmenegger, 2015). For example, socioecological transformation in Kenya's Arid and Semi-Arid Lands is associated with population growth, in-migration, rapid sedentarization, changes in traditional land use and land tenure regimes, high poverty levels, natural resource-based conflicts, and changes in gender roles, among others (Njoka *et al.*, 2016). Moreover, pastoralism is evolving in response to land degradation, increasing frequency of droughts, overgrazing (Kassahun, Snyman and Smit, 2008), the decline in livestock holdings (Elias, 2014), agricultural expansion (Schmidt and Pearson, 2016), and the increasing commoditization and inequality in the livestock economy (Fratkin and Mearns, 2003).

In light of above, any development planning or policymaking in pastoral areas should be based on a sound understanding of the ongoing socioecological trends (Rodgers, 2021). According to ODI (2009), pastoralist trends need to be part of the agenda in drylands development so that the changes and their consequences are taken into account. Besides, Wynants *et al.* (2019) noted that taking the complex drivers of change into consideration and building upon existing linkages between social, economic and ecological demands are keys to the attainment of sustainable land management in pastoral systems. Therefore, understanding the challenges and

opportunities associated with transitions in pastoralism is paramount for the development of appropriate policies and informing interventions (ODI, 2009). Nagash (2021) noted that a holistic understanding of a pastoral system and its transition and the likely trade-offs associated with different livelihood strategies in the system are prerequisites to developing supportive plans and policies that are consistent with existing situations and future expectations. Additionally, Jiang, Niu and Wu (2019) in a study of Inner Mongolia deduced that an improved understanding of changes and the potential drivers may help foster strategies to sustain the pastoral system.

This calls for participatory analysis of the pastoral system to enable a deeper understanding of issues and identification of effective approaches for the management of pastoral resources (Gelan, Getahun and Beyene, 2017). Moreover, Boles *et al.* (2009) pointed out that understanding the connections between different agents and pressures demands nuanced evidence-based analyses rather than *a priori* generalization. Such an analysis should involve a long timescale and be informed by an interdisciplinary analysis to account for the diverse drivers of change (Boles *et al.*, 2009). Furthermore, the analysis should acknowledge the spatiotemporal context and account for historical variability in landscape ontogenies (Boles *et al.*, 2019). According to ODI (2009), though pastoralists are regarded as homogenous groups with the livestock economy at the core of their livelihood systems, the transformation processes in pastoral communities are different. It is also important to note that the potential impacts of the drivers of pastoral transformations, their feedback on each other, and the responses of the pastoral systems vary greatly within and across socioecological contexts (Fratkin and Mearns, 2003; Steinfels, Wassenaar and Jutzi, 2006;). Manzano *et al.* (2021) observed that knowledge gaps caused by studying diverse systems under a single umbrella and a lack of interdisciplinary integration are the reasons behind the development of unfavorable pastoral policies and plans.

This study, therefore, aimed to analyze the socioecological trends of pastoral systems with a focus on Laikipia County, Kenya. The study analyzed how pastoral systems have evolved across demographic, social, economic, environmental and economic dimensions. This was by studying the status of various aspects of pastoral socioecological systems in the past, how they changed along the years, and their current state. Moreover, the study analyzed the drivers behind the observed trends, including the relationships and influences between the various factors under study, feedbacks of these influences, and the ongoing responses within the system. Therefore, the study led to an understanding of the factors that led to the current state of the pastoral socioecological system, and thus how the various challenges facing the community could be addressed and existing opportunities strengthened. The study is, thus, key to informing development planning and policy-making processes in pastoral communities.

Methodology

Description of the Study Area

Laikipia County (Figure 1) lies on the leeward side of Mount Kenya and covers an area of 9,462 km² (Government of Kenya, 2015). The county has a population of 518,560 people and a population density of 74 people per square kilometer, and average household size is 4 people (Government of Kenya, 2019). Laikipia County

experiences a relief type of rainfall whose distribution is strongly influenced by Mount Kenya and the Aberdares Ranges (GLOPP, 2007; Roden *et al.*, 2016). The rainfall ranges between 300 mm in the North to 1,000 mm per annum in the West, and is bimodal but generally erratic (Gichuki *et al.*, 1998; Mwiti, 2006; Roden *et al.*, 2016). The mean temperature in the county is 24°C (Kohler, 1987) and ranges between 16°C and 26°C (Mwangi, 2014). Most of the county falls within the arid and semi-arid agroecological zones with small areas on the foot of the mountain's slopes falling in the sub-humid zone (Sombroek, Braun and Van der Pauw, 1980). Large parts of the county lie in ecological zone IV, but the Northern part falls in agroecological zone V and VI (FAO, 1996).

The soils in the county include volcanic soils, clay loams, black cotton soils, sandy soils, and sandy loam soils (Mwangi, 2014). The soil groups include lavisols, regosols, and lexisols to the North, phaezoms, and vertisols to the East, West, and Southeast, and nitisols in the forest complex near Nyahururu and the surrounding areas (Mwiti, 2006). The geology of the area includes pre-Cambrian, tertiary extrusive and intrusive, and quaternary extrusive and intrusive rocks.

Laikipia County comprises a mosaic of grasslands, bushlands, woodlands, and dry forests in the higher altitude areas (Butynski and De Jong, 2014; Witt, 2017). The County lies at the overlap of the Somali-Maasai bushland biotic zone and the Afromontane-Afro alpine biotic zone (Butynski and De Jong, 2014). Moreover, it falls under two eco-regions, including the Northern Acacia-Commiphora bushlands and thicket and the East African montane forest. The resultant great diversity of vegetation types, ecotones, and mosaics accounts for the high biological diversity of Laikipia County (Butynski and De Jong, 2014). Laikipia County is, thus, home to over 62 large mammal species, i.e. 21 carnivore species, 28 species of ungulates, 8 species of primates, and over 560 bird species (Butynski and De Jong, 2014). However, these habitats are threatened by a host of invasive alien species that are rapidly replacing indigenous vegetation (Witt, 2017).

Laikipia County was originally occupied by specialized hunters and gatherers (LWF, 2012). Early Laikipians included the Cushitic-speaking Yaaku People from Southern Ethiopia who co-existed with indigenous foragers until they were displaced and assimilated by the Nilotc Maa-speaking Laikipiak Maasai in the Eighteenth Century (Carrier, 2011). The original inhabitants were assimilated into the pastoral culture of the Laikipiak Maasai which they also considered to be superior to theirs, although they still practice beekeeping (Cronk, 2004). The arrival of the Europeans as settlers after the establishment of the British East Africa Protectorate in 1895 resulted in a major change in land tenure and use in Laikipia (LWF, 2012). This was, particularly, through the Anglo-Maasai treaties of 1904 and 1911, which led to the Maasai being moved to a Southern Kenya Maasai Reserve and others being confined in the Mukogondo Maasai Native Reserve in the Northern part of Laikipia by the colonial government (Mwiti, 2006; Hughes, 2007; Evans and Adams, 2016). The post-independence period also saw the arrival of other people, mainly from Central Kenya, through government-sponsored land redistribution programs and later on through land-buying companies in the 1960s and the 1970s. Over time, the population of Laikipia continued to grow as people were attracted by the availability of cheap land, grazing resources, and livelihood opportunities.

The settlement patterns in the county are uneven as influenced by their land potential, livelihood zones, infrastructural development, land use systems, river drainage systems, and availability of social amenities (Mwangi, 2014; Government of Kenya, 2015). The more agriculturally favourable landforms an arc around the Eastern, Southern, and Western boundaries of the county hosting most of its population (Weismann, 1998) while the Northern Arid and Semi-arid Lands area has the least population (Government of Kenya, 2015). The population in the county is largely rural (Government of Kenya, 2011).

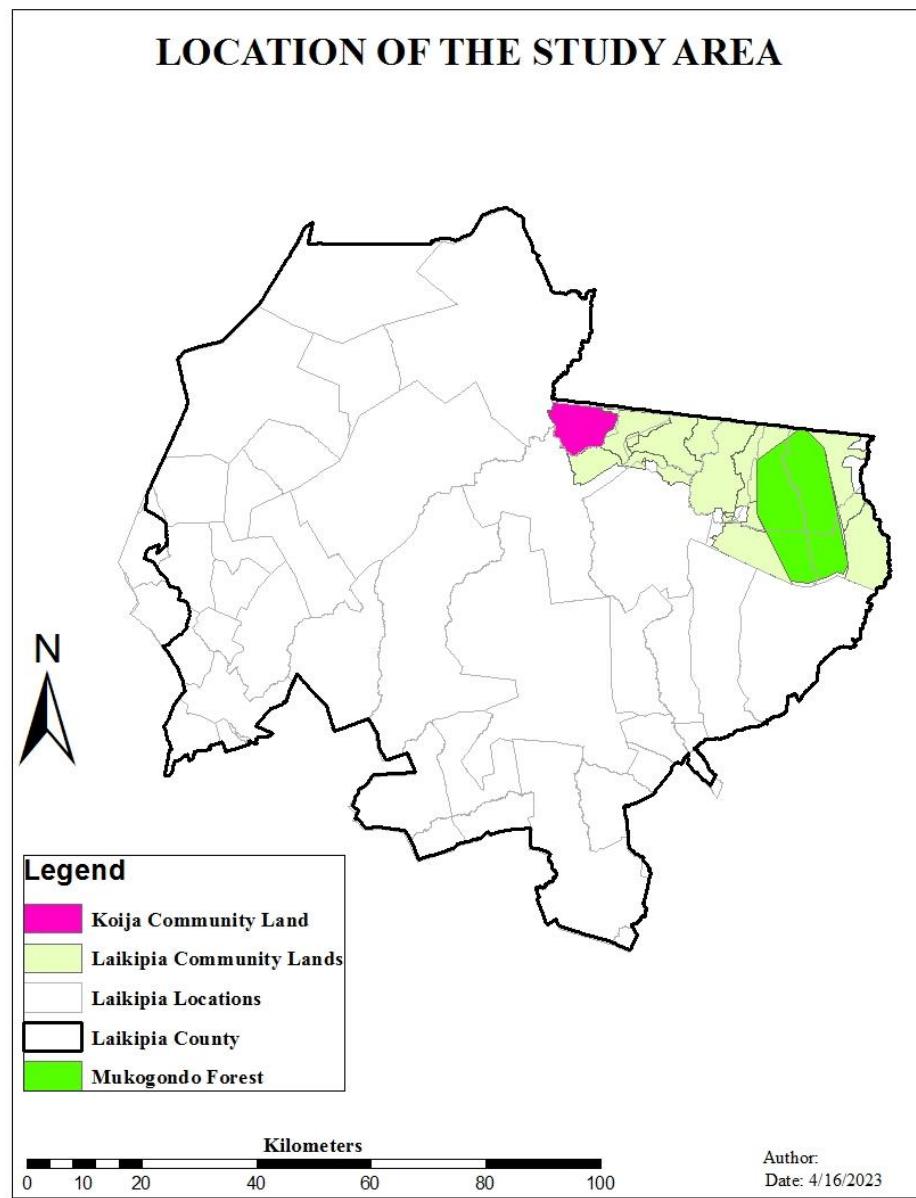


Figure 1: Location of the study area

The average land ownership varies, including smallholders (0.8 hectares), large-scale farmers (80 hectares), community group ranches (23 hectares), and commercial ranchers (10,000 hectares). The land tenure regimes include private, communal, and

public land tenure (Evans and Adams, 2016; LWF, 2012). Although the land was previously held communally, communal land tenure currently only exists in the pastoralists owned Mukogondo community lands in the Northern part. Agriculture is the dominant economic activity and is practiced by 85% of the population (Mwangi, 2014). The area under small-scale farming covers 33% of Laikipia County (Mwiti, 2006). Large-scale farms cover about 2% of Laikipia, mainly located along the rivers where irrigation agriculture is practiced (Mwiti, 2006).

The livestock sector constitutes a major economic activity in Laikipia (Kenya Association of Manufacturers, 2014). A large portion of Laikipia is utilized for ranching, with 43 large-scale ranches occupying about 60% of the county (Mwiti, 2006; Government of Kenya, 2013). These constitute 30 privately owned ranches and 13 community group ranches. The community group ranches are occupied by pastoralists and lie to the North in the Mukogondo Native reserve where the Maasai were restricted during the colonial era and are under communal land tenure (Mwiti, 2006; Government of Kenya, 2013). Most of the ranches in the county host wild animals and engage in wildlife-based, particularly tourism, enterprises.

Sampling Methods

The study used a multi-stage sampling design. First, Laikipia County was purposively chosen for the study. Secondly, Koija community land in Laikipia County was purposively chosen for the study given its wider representation of the Laikipiak Maasai Community and early settlement in the area. Thirdly, purposive sampling was used to choose a diverse group of 20 knowledgeable participants from the community land. The group had representatives from different sections of the community, including women, men, and youth from different age groups.

Research Tools

Data collection and analysis were done using the participatory trend analysis method. The participatory trend analysis was transdisciplinary and focused on changes regarding demographic, social, institutional, environmental and economic dimensions. It involved a participatory quantification of the changes that have occurred over a period of 12 decades, i.e. 1900s to the 1910s. The quantification of the changes was done by rating the status of a given variable in a specific decade against the other decades on a scale of 1 to 10. This yielded a trend line that helped to learn what was getting better and what was getting worse over time. In doing this, the participants first engaged in discussions to identify the most relevant period and intervals for the study. They also identified and settled upon the variables whose changes were to be analyzed for each of the study dimensions. More trends were identified as the discussions proceeded. Discussions were also involved in quantifying the state of the variables. The participants then discussed the interactions and linkages between the different trends to establish their causes and effects. This helped to establish the relationships between the trends. Further, the participants discussed the solutions that have been tried in the past to address the causes, how effective they were, and what could be done better to address the causes based on the analysis.

The trends arrived at through the participatory analysis were tested using the Mann-Kendall statistical Test. The Mann-Kendall statistical test is used to test the direction and significance of increasing or decreasing trends (monotonic trend) in time series data (Pal *et al.*, 2017; Asfaw *et al.*, 2018). The test was computed using MEKESENS, an MS excel template developed by the Finnish Meteorological Department for the detection and estimation of trends (Weldegerima *et al.*, 2018). Further, Kendall's "tau-b correlation coefficient" was used to analyze the relationship between the trends, including their causes and effects. Kendall's "tau-b correlation coefficient" is a measure of rank correlation that measures the similarity of the orderings of the data when ranked by each of the quantities in paired observations (Kendall, 1955).

Measurement of Major Indicators

The measurement of indicators involved a participatory quantification of the changes that have occurred over a period of 12 decades, i.e. 1900s to the 1910s. The quantification of the changes was done by rating the status of a given variable in a specific decade against the other decades on a scale of 1 to 10.

Results

Demographic Trends

The human population in the study area was found to have a significant positive trend ($Z = 4.22, P < 0.001$). The number of households also had a significant positive trend ($Z = 4.22, P < 0.001$). Human population had a significant positive correlation with immigration ($\tau_b = 0.944^{**}, P < 0.01$), and access to government services ($\tau_b = 0.907^{**}, P < 0.01$). Besides, human population had a significant positive correlation with the growth of urban areas ($\tau_b = 0.944^{**}, P < 0.01$), access to employment opportunities ($\tau_b = 0.890^{**}, P < 0.01$), and access to transport services ($\tau_b = 0.933^{**}, P < 0.01$). A significant negative correlation was found between the human population and mortality rates ($\tau_b = -0.959^{**}, P < 0.01$), and livestock mobility ($\tau_b = -0.952^{**}, P < 0.01$).

The size of the households had a significant negative trend ($Z = -4.16, P < 0.001$). The size of the households was found to have a significant positive correlation with the birth rate ($\tau_b = 0.924^{**}, P < 0.01$). Moreover, the size of the household had a significant negative correlation with access to health services ($\tau_b = 0.906^{**}, P < 0.01$), access to education ($\tau_b = -0.942^{**}, P < 0.01$), and women empowerment ($\tau_b = 0.932^{**}, P < 0.01$). A significant positive correlation was also found between the size of the households and land adequacy ($\tau_b = 0.984^{**}, P < 0.01$), livestock ownership per capita ($\tau_b = 0.876^{**}, P < 0.01$), and food security ($\tau_b = 0.882^{**}, P < 0.01$). The birth rate had a significant negative trend ($Z = -3.88, P < 0.001$). The birth rate was found to have a significant negative correlation ($\tau_b = -0.891^{**}, P < 0.01$) with access to health services, access to education ($\tau_b = -0.897^{**}, P < 0.01$), access to information ($\tau_b = -0.926^{**}, P < 0.01$), and women empowerment ($\tau_b = -0.881^{**}, P < 0.01$). The birth rate, however, had a significant positive correlation with livestock ownership per capita ($\tau_b = 0.828^{**}, P < 0.01$), food security ($\tau_b = 0.903^{**}, P < 0.01$), and observation of cultural practices ($\tau_b = 0.992^{**}, P < 0.01$).

The mortality rate in the study area had a significant negative trend ($Z = -4.17$, $P < 0.001$). The mortality rate was found to have a significant negative correlation with access to health services ($\tau_b = -0.889^{**}$, $P < 0.01$). Nevertheless, the morbidity rate was found to have a significant positive trend ($Z = 3.44$, $P < 0.001$). The morbidity rate had a significant positive trend ($Z = 3.44$, $P < 0.001$). The study revealed that morbidity rate had a significant positive correlation with climate change and variability ($\tau_b = 0.821^{**}$, $P < 0.01$), drought frequency and severity ($\tau_b = 0.821^{**}$, $P < 0.01$), land degradation ($\tau_b = 0.824^{**}$, $P < 0.01$), and in-migration ($\tau_b = 0.827^{**}$, $P < 0.01$). Moreover, morbidity had a significant negative correlation with food security ($\tau_b = -0.870^{**}$, $P < 0.01$), water availability, ($\tau_b = -0.794^{**}$, $P < 0.01$), and observation of moral values ($\tau_b = -0.817^{**}$, $P < 0.01$).

The rate of out-migration was found to have a significant positive trend ($Z = 4.05$, $P < 0.001$). Outmigration had a significant positive correlation with access to formal education ($\tau_b = 0.958^{**}$, $P < 0.01$), access to transport services ($\tau_b = 0.938^{**}$, $P < 0.01$), access to communication services ($\tau_b = 0.939^{**}$, $P < 0.01$), and livelihoods diversification ($\tau_b = 0.935^{**}$, $P < 0.01$). Similarly, outmigration had a significant negative correlation with conflicts ($\tau_b = 0.845^{**}$, $P < 0.01$), climate change and variability ($\tau_b = 0.949^{**}$, $P < 0.01$), drought frequency and severity ($\tau_b = 0.949^{**}$, $P < 0.01$), and land degradation ($\tau_b = 0.933^{**}$, $P < 0.01$). Conversely, outmigration was found to have a significant negative correlation with security ($\tau_b = -0.815^{**}$, $P < 0.01$), land adequacy ($\tau_b = -0.968^{**}$, $P < 0.01$), and livestock ownership per capita ($\tau_b = -0.924^{**}$, $P < 0.01$).

The rate of in-migration had a significant positive trend ($Z = 4.17$, $P < 0.001$). In-migration was found to have a significant positive correlation with access to government services ($\tau_b = 0.900^{**}$, $P < 0.01$), access to education ($\tau_b = 0.960^{**}$, $P < 0.01$), and access to health services ($\tau_b = 0.874^{**}$, $P < 0.01$). Moreover, in-migration had a significant positive correlation with access to transport services ($\tau_b = 0.943^{**}$, $P < 0.01$), access to communication services ($\tau_b = 0.909^{**}$, $P < 0.01$), growth of urban areas ($\tau_b = 0.968^{**}$, $P < 0.01$), and access to markets ($\tau_b = 0.976^{**}$, $P < 0.01$). A significant positive correlation was also found between in-migration and livelihoods diversification ($\tau_b = 0.952^{**}$, $P < 0.01$), ecotourism ($\tau_b = 0.880^{**}$, $P < 0.01$), and sand harvesting ($\tau_b = 0.961^{**}$, $P < 0.01$). In addition, in-migration had a significant positive correlation with access to veterinary services ($\tau_b = 0.886^{**}$, $P < 0.01$), and a significant negative correlation with incidences of livestock diseases ($\tau_b = -0.815^{**}$, $P < 0.01$).

The number of female-headed households in the study area was found to have a significant positive trend. The number of female-headed households had a significant positive correlation with access to education ($\tau_b = 0.943^{**}$, $P < 0.01$), outmigration ($\tau_b = 0.935^{**}$, $P < 0.01$), livelihood diversification ($\tau_b = 1.000^{**}$, $P < 0.01$), and women empowerment ($\tau_b = 0.900^{**}$, $P < 0.01$). Conversely, the number of female-headed households had a significant negative correlation with observation of moral values ($\tau_b = -0.944^{**}$, $P < 0.01$), and observation of cultural practices ($\tau_b = -0.944^{**}$, $P < 0.01$).

The analysis of the demographic trends was as shown in table 1.

Table 1: Analysis of demographic trends

#	Trend	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010s	Mann-Kendall (Z) Test	Sig
1	Human population	2	2	3	3	4	4	5	6	7	7	8	9	4.22	***
2	Number of households	1	2	2	3	3	4	5	6	7	7	8	8	4.22	***
3	Size of the households	9	8	8	7	7	6	6	5	5	4	4	3	-4.16	***
4	Birth rate	10	9	9	9	8	8	8	7	7	7	6	6	-3.88	***
5	Mortality rate	9	8	8	8	7	7	6	6	5	4	3	2	-4.17	***
6	Morbidity rate	3	4	5	5	5	6	6	6	8	8	7	7	3.44	***
7	Out-migration	1	1	1	2	2	3	3	4	4	5	5	6	4.05	***
8	In-migration	1	2	2	3	4	5	6	6	7	8	8	9	4.17	***
9	Number of female-headed households	1	1	2	2	3	3	4	6	7	8	9	10	4.28	***

Social Trends

Access to formal education had a significant positive trend ($Z = 4.17, P < 0.001$). Access to education had a significant positive correlation with access to government services ($\tau_b = 0.940^{**}, P < 0.01$), urban growth ($\tau_b = 0.960^{**}, P < 0.01$), women empowerment ($\tau_b = 0.904^{**}, P < 0.01$), infrastructure development ($\tau_b = 0.908^{**}, P < 0.01$), in-migration, ($\tau_b = 0.960^{**}, P < 0.01$), out-migration ($\tau_b = 0.958^{**}, P < 0.01$), and access to information ($\tau_b = 0.943^{**}, P < 0.01$). Access to education had a non-significant positive correlation with community participation in decision-making ($\tau_b = 4.10, P < 0.01$).

Access to modern health services in the area was also found to have a significant positive trend ($Z = 3.88, P < 0.001$). Access to health services had a significant positive correlation with access to government services ($\tau_b = 0.841^{**}, P < 0.01$), access to formal education ($\tau_b = 0.878^{**}, P < 0.01$), access to formal education ($\tau_b = 0.878^{**}, P < 0.01$), women empowerment ($\tau_b = 0.878^{**}, P < 0.01$), infrastructure development ($\tau_b = 0.938^{**}, P < 0.01$), access to transport services ($\tau_b = 0.873^{**}, P < 0.01$), and access to information ($\tau_b = 0.926^{**}, P < 0.01$). Access to health services had a non-significant positive correlation with community participation in decision-making ($\tau_b = 4.15, P > 0.1$).

The study found food security to be declining significantly in the study area ($Z = -3.80, P < 0.001$). The study revealed that food security had a significant positive correlation with number of livestock per household ($\tau_b = 0.838^{**}, P < 0.01$), land adequacy ($\tau_b = 0.868^{**}, P < 0.01$), land tenure security ($\tau_b = 0.671^{**}, P < 0.01$), effectiveness of land management ($\tau_b = 0.739^{**}, P < 0.01$), livestock mobility ($\tau_b = 0.942^{**}, P < 0.01$), and social cohesion ($\tau_b = 0.899^{**}, P < 0.01$). In addition, food security had a significant positive correlation with security ($\tau_b = 0.739^{**}, P < 0.01$), rainfall amount ($\tau_b = 0.805^{**}, P < 0.01$), stream flow ($\tau_b = 0.884^{**}, P < 0.01$), pasture availability ($\tau_b = 0.884^{**}, P < 0.01$), and honey production ($\tau_b = 0.918^{**}, P < 0.01$). However, food security had a significant negative correlation with climate change and variability ($\tau_b = -0.931^{**}, P < 0.01$), drought frequency and severity ($\tau_b = -0.931^{**}, P < 0.01$), land degradation ($\tau_b = -0.950^{**}, P < 0.01$), and conflicts ($\tau_b = -0.772^{**}, P < 0.01$).

Food diversity had a significant positive trend ($Z = 4.28, P < 0.001$). The study revealed that food diversity has a significant positive correlation with livelihood diversification ($\tau_b = 0.968^{**}, P < 0.01$), urban growth ($\tau_b = 0.968^{**}, P < 0.01$), human population ($\tau_b = 0.960^{**}, P < 0.01$), in-migration ($\tau_b = 0.968^{**}, P < 0.01$), outmigration ($\tau_b = -0.968^{**}, P < 0.01$), formal education access ($\tau_b = 0.960^{**}, P < 0.01$), and access to health services ($\tau_b = 0.909^{**}, P < 0.01$). Further, food diversity had a significant positive correlation with drought frequency and severity ($\tau_b = 0.951^{**}, P < 0.01$), climate change and variability ($\tau_b = 0.951^{**}, P < 0.01$), land degradation ($\tau_b = 0.968^{**}, P < 0.01$), conflicts ($\tau_b = 0.818^{**}, P < 0.01$), farming activities ($\tau_b = 0.960^{**}, P < 0.01$), access to markets ($\tau_b = 0.960^{**}, P < 0.01$), access to information ($\tau_b = 0.988^{**}, P < 0.01$), access to transport services ($\tau_b = 0.943^{**}, P < 0.01$), and access to communication services ($\tau_b = 0.909^{**}, P < 0.01$). Besides, food diversity had a significant negative correlation with livestock mobility ($\tau_b = -0.960^{**}, P < 0.01$), number of livestock per household ($\tau_b = -0.911^{**}, P < 0.01$), observation of cultural practices ($\tau_b = -0.976^{**}, P < 0.01$), and food security ($\tau_b = -0.901^{**}, P < 0.01$).

Women empowerment also had a significant positive trend ($Z = 3.74, P < 0.001$). The study found that women empowerment has a significant positive correlation with access to formal education ($\tau_b = 0.904^{**}, P < 0.01$), access to information ($\tau_b = 0.900^{**}, P < 0.01$), community participation in decision making ($\tau_b = 0.491^*, P < 0.05$), and access to government services ($\tau_b = 0.943^{**}, P < 0.01$). Further, women empowerment also had a significant positive correlation with out-migration ($\tau_b = 0.948^{**}, P < 0.01$), in-migration ($\tau_b = 0.900^{**}, P < 0.01$), access to credit ($\tau_b = 0.932^{**}, P < 0.01$), and livelihoods diversification ($\tau_b = 0.900^{**}, P < 0.01$).

The observation of moral values had declined significantly over time ($Z = -4.22, P < 0.001$). The observation of moral values had a significant positive correlation with observation of cultural practices ($\tau_b = 0.952^{**}, P < 0.01$), effectiveness of customary governance systems ($\tau_b = 0.934^{**}, P < 0.01$), social cohesion and ($\tau_b = 0.959^{**}, P < 0.01$). However, observation of moral values had a significant negative correlation with in-migration ($\tau_b = -0.976^{**}, P < 0.01$), out-migration ($\tau_b = 0.942^{**}, P < 0.01$), and urban growth ($\tau_b = 0.944^{**}, P < 0.01$). The observation of cultural practices has also declined significantly over time ($Z = -4.22, P < 0.001$). The observation of cultural practices was found to have a significant positive correlation with the effectiveness of customary governance systems ($\tau_b = 0.917^{**}, P < 0.01$), observation of moral values ($\tau_b = 0.952^{**}, P < 0.01$), and social cohesion ($\tau_b = 0.943^{**}, P < 0.01$). Conversely, the observation of cultural practices had a significant negative correlation with access to government services ($\tau_b = -0.872^{**}, P < 0.01$), access to formal education ($\tau_b = -0.935^{**}, P < 0.01$), access to communication services ($\tau_b = -0.916^{**}, P < 0.01$), and access to information ($\tau_b = -0.944^{**}, P < 0.01$). Still, the observation of cultural practices had a significant negative correlation with in-migration ($\tau_b = -0.960^{**}, P < 0.01$), out-migration ($\tau_b = -0.976^{**}, P < 0.01$), livelihoods diversification ($\tau_b = -0.944^{**}, P < 0.01$), access to markets ($\tau_b = -0.935^{**}, P < 0.01$), and the growth of urban areas ($\tau_b = -0.944^{**}, P < 0.01$).

Social cohesion in the community was found to have a significant negative trend ($Z = -4.17, P < 0.001$). The study found that social cohesion has a significant positive correlation the observation of cultural practices ($\tau_b = 0.943^{**}, P < 0.01$), observation of moral values ($\tau_b = -0.959^{**}, P < 0.01$), and the effectiveness of customary governance

systems ($\tau_b = 0.917^{**}$, $P < 0.01$). However, social cohesion had a significant negative correlation with outmigration ($\tau_b = -0.976^{**}$, $P < 0.01$), in-migration ($\tau_b = -0.952^{**}$, $P < 0.01$), urban growth ($\tau_b = -0.952^{**}$, $P < 0.01$), access to markets ($\tau_b = -0.976^{**}$, $P < 0.01$), land privatization ($\tau_b = -0.926^{**}$, $P < 0.01$), income inequality ($\tau_b = -0.943^{**}$, $P < 0.01$), and livelihood diversification ($\tau_b = -0.944^{**}$, $P < 0.01$).

Income inequality was found to have a significant positive trend ($Z = 4.22$, $P < 0.001$). Income inequality had a significant positive correlation with urban growth ($\tau_b = 0.976^{**}$, $P < 0.01$), climate change and variability ($\tau_b = 0.942^{**}$, $P < 0.01$), drought frequency and severity ($\tau_b = 0.942^{**}$, $P < 0.01$), land degradation ($\tau_b = 0.959^{**}$, $P < 0.01$), conflicts ($\tau_b = 0.807^{**}$, $P < 0.01$), and privatization of land ($\tau_b = 0.967^{**}$, $P < 0.01$). Conversely, income inequality had a significant negative correlation with number of livestock per household ($\tau_b = -0.885^{**}$, $P < 0.01$), social cohesion ($\tau_b = -0.943^{**}$, $P < 0.01$), security ($\tau_b = -0.778^{**}$, $P < 0.01$), livestock mobility ($\tau_b = 0.935^{**}$, $P < 0.01$), land tenure security ($\tau_b = -0.644^{**}$, $P < 0.01$), and land adequacy ($\tau_b = -0.960^{**}$, $P < 0.01$).

The analysis of social trends was as shown in table 2.

Table 2: Analysis of social trends

#	Trend	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010s	Mann-Kendall (Z) Test	Sig
1	Access to formal education	0	0	0	1	1	2	3	3	4	4	5	6	4.11	***
2	Access to health services	0	0	1	1	1	1	2	2	3	5	6	3.88		***
3	Food security	8	8	7	7	7	6	6	5	4	5	4	4	-3.80	***
4	Food diversity	2	2	3	4	4	5	6	7	8	9	9	10	4.28	***
5	Women empowerment	1	1	1	1	1	2	2	3	3	4	4	5	3.74	***
6	Observation of moral values	10	9	9	8	8	7	6	6	5	5	4	3	-4.22	***
7	Observation of cultural practices														
8	Social cohesion	10	10	10	9	8	7	6	6	5	5	4	3	-4.17	***
9	Income inequality	3	3	4	4	5	5	6	7	8	9	9	10	4.22	***

Institutional Trends

Access to government services was found to have a significant positive trend in the study area ($Z = 3.74$, $P < 0.001$). Access to government services has a significant positive correlation with community participation in decision making ($\tau_b = 0.509^*$, $P < 0.05$), urban growth ($\tau_b = 0.917^{**}$, $P < 0.01$), human population ($\tau_b = 0.907^{**}$, $P < 0.01$), infrastructure development ($\tau_b = 0.858^{**}$, $P < 0.01$), access to transport services ($\tau_b = 0.899^{**}$, $P < 0.01$), access to communication services ($\tau_b = 0.899^{**}$, $P < 0.01$), and access to information ($\tau_b = 0.900^{**}$, $P < 0.01$). Additionally, access to government services has a significant positive correlation with access to markets ($\tau_b = 0.925^{**}$, $P < 0.01$), demand for livestock and livestock products ($\tau_b = 0.932^{**}$, $P < 0.01$), sand harvesting ($\tau_b = 0.910^{**}$, $P < 0.01$), and ecotourism activities ($\tau_b = 0.855^{**}$, $P < 0.01$). Access to government services had a significant negative correlation with the effectiveness of customary governance systems ($\tau_b = -0.866^{**}$, $P < 0.01$).

Security in the area had a significant negative trend ($Z = -3.22$, $P < 0.001$). The study found security has a significant positive correlation with observation of moral values ($\tau_b = 0.778^{**}$, $P < 0.01$), observation of cultural practices ($\tau_b = 0.760^{**}$, $P < 0.01$), effectiveness of customary governance systems ($\tau_b = 0.733^{**}$, $P < 0.01$), and social cohesion ($\tau_b = 0.819^{**}$, $P < 0.01$). Moreover, security has a significant positive correlation with adequacy of land ($\tau_b = 0.754^{**}$, $P < 0.01$), food security ($\tau_b = -0.739^*$, $P < 0.01$), water availability ($\tau_b = 0.772^{**}$, $P < 0.01$), and pasture availability ($\tau_b = 0.772^{**}$, $P < 0.01$). Conversely, security has a significant negative correlation with land degradation ($\tau_b = -0.801^{**}$, $P < 0.01$), in-migration ($\tau_b = -0.772^{**}$, $P < 0.01$), income inequalities ($\tau_b = -0.889^{**}$, $P < 0.01$), and conflicts ($\tau_b = -0.973^{**}$, $P < 0.01$).

Conflict incidences were found to have a significant positive trend ($Z = 3.39$, $P < 0.001$). Conflict incidences were found to have a significant positive correlation with land degradation ($\tau_b = 0.831^{**}$, $P < 0.01$), droughts frequency and severity ($\tau_b = 0.828^{**}$, $P < 0.01$), climate change and variability ($\tau_b = 0.828^{**}$, $P < 0.01$), and income inequalities ($\tau_b = 0.931^{**}$, $P < 0.01$). Also, conflict incidences have a significant positive correlation with in-migration ($\tau_b = 0.784^{**}$, $P < 0.01$), outmigration ($\tau_b = 0.845^{**}$, $P < 0.01$), human population ($\tau_b = 0.807^{**}$, $P < 0.01$), land privatization ($\tau_b = 0.752^{**}$, $P < 0.01$), crop production ($\tau_b = 0.841^{**}$, $P < 0.01$), establishment of nature conservation areas ($\tau_b = 0.811^{**}$, $P < 0.01$), and number of livestock ($\tau_b = 0.526^*$, $P < 0.05$). On the other hand, conflict incidences have a significant negative correlation with security ($\tau_b = -0.973^{**}$, $P < 0.01$), observation of moral values ($\tau_b = -0.791^{**}$, $P < 0.01$), effectiveness of customary governance systems ($\tau_b = -0.730^{**}$, $P < 0.01$), and social cohesion ($\tau_b = -0.848^{**}$, $P < 0.01$). Further, conflict incidences have a significant negative correlation with water availability ($\tau_b = -0.801^{**}$, $P < 0.01$), pasture availability ($\tau_b = -0.801^*$, $P < 0.01$), number of livestock per household ($\tau_b = -0.906^*$, $P < 0.01$), food security ($\tau_b = -0.772^*$, $P < 0.01$), and land adequacy ($\tau_b = -0.784^{**}$, $P < 0.01$).

Community participation in decision-making had a non-significant positive trend ($Z = 1.41$, $P > 0.1$). Community participation in decision-making was found to have a non-significant positive correlation with access to formal education ($\tau_b = 0.410$, $P > 0.05$) and access to information ($\tau_b = 0.367$, $P > 0.05$). Besides community participation in decision-making has a significant positive with women's empowerment ($\tau_b = 0.491^*$, $P < 0.05$) and access to government services ($\tau_b = 0.509^*$, $P < 0.05$). Community participation in decision-making had a non-significant negative correlation with the effectiveness of customary systems ($\tau_b = -0.261$, $P > 0.05$). The effectiveness of customary governance systems had a significant negative trend ($Z = -0.401$, $P < 0.001$). The effectiveness of customary governance systems was found to have a significant positive correlation with the observation of cultural practices ($\tau_b = 0.917^{**}$, $P < 0.01$), observation of moral values ($\tau_b = 0.934^{**}$, $P < 0.01$), security ($\tau_b = 0.733^{**}$, $P < 0.01$), land tenure security ($\tau_b = 0.685^{**}$, $P < 0.01$), and social cohesion ($\tau_b = 0.908^{**}$, $P < 0.01$). However, the effectiveness of customary governance systems had a significant negative correlation with access to government services ($\tau_b = -0.866^{**}$, $P < 0.01$), in-migration ($\tau_b = -0.926^{**}$, $P < 0.01$), outmigration ($\tau_b = -0.889^{**}$, $P < 0.01$), urban growth ($\tau_b = -0.926^{**}$, $P < 0.01$), privatization of land ($\tau_b = 0.915^{**}$, $P < 0.01$), climate change and variability ($\tau_b = -0.906^{**}$, $P < 0.01$), and conflicts ($\tau_b = -0.730^{**}$, $P < 0.01$).

The effectiveness of land management was also found to have significantly declined over time ($Z = -3.37$, $P < 0.001$). The effectiveness of land management has a significant positive correlation with security ($\tau_b = 0.611^*$, $P < 0.05$), effectiveness of traditional governance systems ($\tau_b = 0.911^{**}$, $P < 0.01$), observation of moral values ($\tau_b = 0.812^{**}$, $P < 0.01$), and social cohesion ($\tau_b = 0.767^{**}$, $P < 0.01$). In addition, the effectiveness of land management has a significant positive correlation with livestock mobility ($\tau_b = 0.812^{**}$, $P < 0.01$), land adequacy ($\tau_b = 0.772^{**}$, $P < 0.01$), and land tenure security ($\tau_b = 0.649^*$, $P < 0.05$). Conversely, the effectiveness of land management has significant negative correlation with conflicts ($\tau_b = -0.577^*$, $P < 0.05$), human population ($\tau_b = -0.795^{**}$, $P < 0.01$), and climate change and variability ($\tau_b = -0.762^{**}$, $P < 0.01$).

Land tenure security was found to have a significant negative trend ($Z = -2.57$, $P < 0.1$). Land tenure security had a significant positive correlation with effectiveness of customary governance systems ($\tau_b = 0.685^{**}$, $P < 0.01$), effectiveness of land management ($\tau_b = 0.649^*$, $P < 0.05$), social cohesion ($\tau_b = 0.630^{**}$, $P < 0.01$), and land adequacy ($\tau_b = 0.620^*$, $P < 0.05$). A non-significant positive correlation was found between land tenure security and security ($\tau_b = 0.426$, $P > 0.05$). In addition, a significant negative correlation was found between land tenure security and human population ($\tau_b = -0.644^{**}$, $P < 0.01$), in-migration ($\tau_b = -0.657^{**}$, $P < 0.01$), establishment of nature conservation reserves ($\tau_b = -0.652^{**}$, $P < 0.01$), and privatization of land ($\tau_b = -0.693^{**}$, $P < 0.01$). Moreover, a significant negative correlation was found between land tenure security and farming activities ($\tau_b = -0.606^{**}$, $P < 0.01$), income inequality ($\tau_b = -0.644^{**}$, $P < 0.01$), access to markets ($\tau_b = -0.625^{**}$, $P < 0.01$), and the growth of urban areas ($\tau_b = -0.657^{**}$, $P < 0.01$). A non-significant negative correlation was found between land tenure security and conflicts ($\tau_b = -0.415$, $P > 0.05$).

The establishment of nature conservation reserves had a significant positive trend ($Z = 4.34$, $P > 0.1$). The establishment of nature conservation reserves had a significant positive correlation with access to government services ($\tau_b = 0.910^{**}$, $P < 0.01$), ecotourism ($\tau_b = 0.937^{**}$, $P < 0.01$), livelihood diversification ($\tau_b = 0.976^{**}$, $P < 0.01$), and land degradation ($\tau_b = 0.960^{**}$, $P < 0.01$). The establishment of nature conservation reserves had a significant negative correlation with wildlife abundance ($\tau_b = -0.961^*$, $P < 0.05$), and security ($\tau_b = -0.782^*$, $P < 0.05$).

The privatization of land had a significant positive trend ($Z = 4.11$, $P > 0.1$). The privatization of land had a significant positive correlation with urban growth ($\tau_b = 0.943^{**}$, $P < 0.01$), access to markets ($\tau_b = 0.918^{**}$, $P < 0.01$), human population ($\tau_b = 0.951^{**}$, $P < 0.01$), access to government services ($\tau_b = 0.869^{**}$, $P < 0.01$), crop production ($\tau_b = 0.918^{**}$, $P < 0.01$), and livelihood diversification ($\tau_b = 0.960^{**}$, $P < 0.01$). Besides, privatization of land had a significant negative correlation with land tenure security ($\tau_b = -0.693^{**}$, $P < 0.01$), effectiveness of customary governance systems ($\tau_b = -0.915^{**}$, $P < 0.01$), social cohesion ($\tau_b = -0.926^{**}$, $P < 0.01$), and livestock mobility ($\tau_b = -0.935^{**}$, $P < 0.01$).

The study found that access to extension services had a significant positive trend ($Z = 3.77$, $P < 0.001$). Access to extension services was found to have a significant positive correlation with access to government services ($\tau_b = 0.876^{**}$, $P < 0.01$), access to

education ($\tau_b = 0.874^{**}$, $P<0.01$), access to information ($\tau_b = 0.886^{**}$, $P<0.01$), access to communication services ($\tau_b = 0.818^{**}$, $P<0.01$), and access to transport services ($\tau_b = 0.852^{**}$, $P<0.01$). Furthermore, access to extension services had a significant positive correlation with human population ($\tau_b = 0.876^{**}$, $P<0.01$), total number of livestock ($\tau_b = 0.638^{**}$, $P<0.01$), and farming activities ($\tau_b = 0.860^{**}$, $P<0.01$). Access to extension services had a non-significant positive correlation with community participation in decision-making ($\tau_b = 0.310$, $P>0.05$).

Access to veterinary services had a significant positive trend ($Z = 3.77$, $P<0.001$). Access to veterinary services was found to have a significant positive correlation with access to government services ($\tau_b = 0.876^{**}$, $P<0.01$), access to education ($\tau_b = 0.874^{**}$, $P<0.01$), access to information ($\tau_b = 0.886^{**}$, $P<0.01$), access to communication services ($\tau_b = 0.818^{**}$, $P<0.01$), and access to transport services ($\tau_b = 0.852^{**}$, $P<0.01$). Furthermore, access to veterinary services had a significant positive correlation with the human population ($\tau_b = 0.876^{**}$, $P<0.01$), and the total number of livestock ($\tau_b = 0.638^{**}$, $P<0.01$). Access to veterinary services had a non-significant positive correlation with community participation in decision-making ($\tau_b = 0.310$, $P>0.05$). Livestock mobility had also decreased significantly ($Z = 3.81$, $P<0.001$). Livestock mobility was found to have a significant positive correlation with land adequacy ($\tau_b = 0.944^{**}$, $P<0.01$), observation of cultural practices ($\tau_b = 0.968^{**}$, $P<0.01$), effectiveness of customary governance systems ($\tau_b = 0.951^{**}$, $P<0.01$), social cohesion ($\tau_b = 0.959^{**}$, $P<0.01$), and security ($\tau_b = 0.760^{**}$, $P<0.01$). Conversely, livestock mobility had a significant negative correlation with human population ($\tau_b = -0.952^{**}$, $P<0.01$), urban growth ($\tau_b = -0.944^{**}$, $P<0.01$), access to government services ($\tau_b = -0.907^{**}$, $P<0.01$), infrastructure development ($\tau_b = -0.926^{**}$, $P<0.01$), conflicts ($\tau_b = -0.791^{**}$, $P<0.01$), land privatization ($\tau_b = -0.935^{**}$, $P<0.01$), establishment of nature conservation reserves ($\tau_b = -0.968^{**}$, $P<0.01$), and farming activities ($\tau_b = -0.952^{**}$, $P<0.01$).

The analysis of institutional trends was as shown in table 3.

Environmental Trends

Climate change and variability in the study area have a significant positive trend ($Z = 4.05$, $P<0.001$). Rainfall amount was found to be declining significantly ($Z = -3.62$, $P<0.001$). The rainfall amount was found to have a significant negative correlation with climate change and variability ($\tau_b = -0.884^{**}$, $P<0.01$). In addition, the frequency and severity of drought were observed to be having a significant positive trend ($Z = 4.05$, $P<0.001$). The frequency and severity of drought were found to have a significant positive correlation with climate change and variability ($\tau_b = 1.000^{**}$, $P<0.01$). The study found that climate change and variability had a significant positive correlation with human population ($\tau_b = 0.942^{**}$, $P<0.01$), livestock numbers ($\tau_b = 0.724^{**}$, $P<0.01$), growth of urban areas ($\tau_b = 0.961^{**}$, $P<0.01$), farming activities ($\tau_b = 0.926^{**}$, $P<0.01$), and land degradation ($\tau_b = 0.967^{**}$, $P<0.01$). Conversely, climate change and variability had a significant negative correlation with tree cover ($\tau_b = -0.926^{**}$, $P<0.01$), and the effectiveness of land management ($\tau_b = -0.762^{**}$, $P<0.01$).

Land degradation had a significant positive trend ($Z = 4.17$, $P<0.001$). A significant positive correlation was found between land degradation and human population ($\tau_b =$

0.976**, P<0.01), urban growth ($\tau_b = 0.968**$, P<0.01), climate change and variability ($\tau_b = 0.967**$, P<0.01), and number of livestock ($\tau_b = 0.695**$, P<0.01). Still, land degradation had a significant positive correlation with sand harvesting ($\tau_b = 0.976**$, P<0.01), demand for livestock products ($\tau_b = 0.951**$, P<0.01), demand for wood tree products ($\tau_b = 0.943**$, P<0.01), and demand for herbs products ($\tau_b = 0.933**$, P<0.01). Further, land degradation was found to have a significant negative correlation with livestock mobility ($\tau_b = -0.959**$, P<0.01), land adequacy ($\tau_b = -0.936**$, P<0.01), land tenure security ($\tau_b = -0.649**$, P<0.01), effectiveness of customary governance systems ($\tau_b = -0.908**$, P<0.01), and effectiveness of land management ($\tau_b = -0.767**$, P<0.01).

Table 3: Analysis of institutional trends

#	Trend	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010s	Mann-Kendall (Z) Test	Sig
1	Access to government services	1	1	1	1	1	2	3	3	4	4	5	5	3.74	***
2	Security	8	9	9	9	9	8	8	8	7	6	5	4	-3.22	**
3	Conflicts incidences	3	2	2	2	2	3	3	4	6	7	8	9	3.39	***
4	Community Involvement in decision making	5	4	3	3	2	2	3	3	4	5	6	7	1.41	
5	Effectiveness of customary governance systems	10	8	7	6	5	5	5	5	4	4	3	3	-4.01	***
6	Effectiveness of land management	10	8	7	6	5	5	5	6	5	5	4	4	-3.37	***
7	Land tenure security	9	7	4	4	4	4	3	4	3	3	3	4	-2.57	*
8	Establishment of nature conservation reserves	0	0	1	2	3	4	5	6	7	8	9	9	4.34	***
9	Land privatization	0	4	5	5	6	6	7	8	8	9	9	9	4.11	***
10	Access to extension services	0	0	1	1	1	2	3	3	4	5	5	4	3.77	***
11	Access to veterinary services	0	0	1	1	1	2	3	3	4	5	5	4	3.77	***
12	Livestock mobility	10	9	7	6	6	5	5	4	3	3	2	2	-4.22	***

The prevalence of invasive species was also found to have a significant positive trend ($Z = 4.28$, P<0.001). The prevalence of invasive species had a significant positive correlation with land degradation ($\tau_b = 0.968**$, P<0.01), climate change and variability ($\tau_b = 0.951**$, P<0.01), and drought frequency and severity ($\tau_b = 0.951**$, P<0.01). Likewise, the prevalence of invasive species had a significant positive correlation with the number of livestock ($\tau_b = 0.734**$, P<0.01), human population ($\tau_b = 0.992**$, P<0.01), and in-migration ($\tau_b = 0.952**$, P<0.01). Contrariwise, the prevalence of invasive species had a significant negative correlation with land adequacy ($\tau_b = -0.952**$, P<0.01), land tenure security ($\tau_b = -0.639**$, P<0.01), the effectiveness of customary governance systems ($\tau_b = -0.926**$, P<0.01), and the effectiveness of land management ($\tau_b = -0.789**$, P<0.01).

Stream flows in the study area were found to have a significant negative trend ($Z = -4.28$, P<0.001). Stream flow was found to have a significant positive correlation with

tree cover ($\tau_b = 0.960^{**}$, $P<0.01$), rainfall amount ($\tau_b = 0.873^{**}$, $P<0.01$), effectiveness of customary governance systems ($\tau_b = 0.926^{**}$, $P<0.01$), effectiveness of land management ($\tau_b = 0.789^{**}$, $P<0.01$), and land adequacy ($\tau_b = 0.984^{**}$, $P<0.01$). Conversely, stream flow had a significant negative correlation with climate change and variability ($\tau_b = -0.951^{**}$, $P<0.01$), drought frequency and severity ($\tau_b = -0.951^{**}$, $P<0.01$), and land degradation ($\tau_b = -0.936^{**}$, $P<0.01$). Similarly, stream flow had a significant negative correlation with human population ($\tau_b = -0.944^{**}$, $P<0.01$), farming activities ($\tau_b = -0.960^{**}$, $P<0.01$), and sand harvesting ($\tau_b = -0.961^{**}$, $P<0.01$). The study found that water availability had a significant negative trend ($Z = -4.28$, $P<0.001$). Water availability had a significant positive correlation with rainfall amount ($\tau_b = 0.873^{**}$, $P<0.01$), river flow ($\tau_b = 1.000^{**}$, $P<0.01$), tree cover ($\tau_b = 0.960^{**}$, $P<0.01$), effectiveness of land management ($\tau_b = 0.789^{**}$, $P<0.01$), and effectiveness of customary land management ($\tau_b = 0.926^{**}$, $P<0.01$). On the contrary, water availability had a significant negative correlation with climate change and variability ($\tau_b = -0.951^{**}$, $P<0.01$), drought frequency and severity ($\tau_b = -0.951^{**}$, $P<0.01$), sand harvesting ($\tau_b = -0.961^{**}$, $P<0.01$), farming activities ($\tau_b = -0.960^{**}$, $P<0.01$), human population ($\tau_b = -0.944^{**}$, $P<0.01$), privatization of land ($\tau_b = -0.943^{**}$, $P<0.01$), establishment of conservation reserves ($\tau_b = -0.961^{**}$, $P<0.01$), and urban growth ($\tau_b = -0.952^{**}$, $P<0.01$).

Tree cover was found to be decreasing significantly ($Z = -4.22$, $P<0.001$). Tree cover was found to have a significant positive correlation with rainfall amount ($\tau_b = 0.844^{**}$, $P<0.01$), effectiveness of customary land governance ($\tau_b = 0.951^{**}$, $P<0.01$), land adequacy ($\tau_b = 0.960^{**}$, $P<0.01$), land tenure security ($\tau_b = 0.682^{**}$, $P<0.01$), and effectiveness of land management ($\tau_b = 0.839^{**}$, $P<0.01$). Contrarily, tree cover had a significant negative correlation with drought frequency and severity ($\tau_b = -0.926^{**}$, $P<0.01$), climate change and variability ($\tau_b = -0.926^{**}$, $P<0.01$), land degradation ($\tau_b = -0.943^{**}$, $P<0.01$), number of livestock ($\tau_b = -0.690^{**}$, $P<0.01$), and farming activities ($\tau_b = -0.968^{**}$, $P<0.01$). Additionally, tree cover had a significant negative correlation with human population ($\tau_b = -0.952^{**}$, $P<0.01$), urban growth ($\tau_b = -0.960^{**}$, $P<0.01$), demand for wood tree products ($\tau_b = -0.968^{**}$, $P<0.01$), and access to transport services ($\tau_b = -0.933^{**}$, $P<0.01$).

The availability of pasture was observed to be decreasing significantly over time ($Z = -4.28$, $P<0.001$). Pasture availability was found to have a significant positive correlation with rainfall amount ($\tau_b = 0.891^{**}$, $P<0.01$), social cohesion ($\tau_b = 0.952^{**}$, $P<0.01$), security ($\tau_b = 0.772^{**}$, $P<0.01$), and effectiveness of customary governance systems ($\tau_b = 0.926^{**}$, $P<0.01$). Moreover, pasture availability had a significant positive correlation with land adequacy ($\tau_b = 0.968^{**}$, $P<0.01$), livestock mobility ($\tau_b = 0.944^{**}$, $P<0.01$), land tenure security ($\tau_b = 0.620^*$, $P<0.05$), and the effectiveness of land management ($\tau_b = 0.789^{**}$, $P<0.01$). Besides, pasture availability was found to have a significant negative correlation with drought frequency and severity ($\tau_b = -0.951^{**}$, $P<0.01$), climate change and variability ($\tau_b = -0.951^{**}$, $P<0.01$), prevalence of invasive species ($\tau_b = -0.984^{**}$, $P<0.01$), land degradation ($\tau_b = -0.952^{**}$, $P<0.01$), and the total number of livestock ($\tau_b = -0.751^{**}$, $P<0.01$). Also pasture availability had a significant negative correlation with human population ($\tau_b = -0.976^{**}$, $P<0.01$), in-migration ($\tau_b = -0.952^{**}$, $P<0.01$), land privatization ($\tau_b = -0.960^{**}$, $P<0.01$), farming activities ($\tau_b = -0.960^{**}$, $P<0.01$), and establishment of nature conservation reserves ($\tau_b = -0.976^{**}$, $P<0.01$).

The availability of herbs in the area had a significant negative trend ($Z = -4.22$, $P < 0.001$). The availability of herbs was found to have a significant positive correlation with rainfall amount ($\tau_b = 0.862^{**}$, $P < 0.01$), land adequacy ($\tau_b = 0.944^{**}$, $P < 0.01$), land tenure security ($\tau_b = 0.663^{**}$, $P < 0.01$), effectiveness of customary governance systems ($\tau_b = 0.934^{**}$, $P < 0.01$), and effectiveness of land management ($\tau_b = 0.812^{**}$, $P < 0.01$). To the contrary, the availability of herbs had a significant negative correlation with land degradation ($\tau_b = -0.976^{**}$, $P < 0.01$), drought frequency and severity ($\tau_b = -0.942^{**}$, $P < 0.01$), climate change and variability ($\tau_b = -0.942^{**}$, $P < 0.01$), human population ($\tau_b = -0.984^{**}$, $P < 0.01$), and demand for herbs products ($\tau_b = -0.942^{**}$, $P < 0.01$).

Wildlife abundance in the study area had a significant negative trend ($Z = -4.28$, $P < 0.001$). Wildlife abundance was found to have a significant positive correlation with rainfall amount ($\tau_b = 0.873^{**}$, $P < 0.01$), water availability ($\tau_b = 0.968^{**}$, $P < 0.01$), pasture availability ($\tau_b = 0.984^{**}$, $P < 0.01$), livestock mobility ($\tau_b = 0.944^{**}$, $P < 0.01$), and tree cover ($\tau_b = 0.944^{**}$, $P < 0.01$). Likewise, the study found wildlife abundance to have a significant positive correlation with security ($\tau_b = 0.737^{**}$, $P < 0.01$), effectiveness of customary land governance systems ($\tau_b = 0.926^{**}$, $P < 0.01$), land adequacy ($\tau_b = 0.984^{**}$, $P < 0.01$), observation of cultural practices ($\tau_b = 0.976^{**}$, $P < 0.01$), observation of moral values ($\tau_b = 0.944^{**}$, $P < 0.01$), and effectiveness of land management ($\tau_b = 0.789^{**}$, $P < 0.01$). Further, wildlife abundance had a significant negative correlation with human population ($\tau_b = -0.960^{**}$, $P < 0.01$), number of households ($\tau_b = -0.944^{**}$, $P < 0.01$), urban growth ($\tau_b = -0.952^{**}$, $P < 0.01$), total number of livestock ($\tau_b = -0.784^{**}$, $P < 0.01$), conflicts ($\tau_b = -0.768^{**}$, $P < 0.01$), farming activities ($\tau_b = -0.944^{**}$, $P < 0.01$), and land privatization ($\tau_b = -0.976^{**}$, $P < 0.01$). Also, wildlife abundance had a significant negative correlation with drought frequency and severity ($\tau_b = -0.935^{**}$, $P < 0.01$), climate change and variability ($\tau_b = -0.935^{**}$, $P < 0.01$), land degradation ($\tau_b = -0.936^{**}$, $P < 0.01$), prevalence of invasive species ($\tau_b = -0.968^{**}$, $P < 0.01$), and stream flow ($\tau_b = -0.968^{**}$, $P < 0.01$).

The abundance of bees also had a significant negative trend ($Z = -4.11$, $P < 0.001$). Bee's abundance was found to have a significant positive correlation with tree cover ($\tau_b = 0.935^{**}$, $P < 0.01$), water availability ($\tau_b = 0.960^{**}$, $P < 0.01$), rainfall amount ($\tau_b = 0.895^{**}$, $P < 0.01$), effectiveness of land management ($\tau_b = 0.755^{**}$, $P < 0.01$), and effectiveness of customary governance systems ($\tau_b = 0.898^{**}$, $P < 0.01$). To the contrary, bee's abundance had a significant negative correlation with human population ($\tau_b = -0.951^{**}$, $P < 0.01$), land degradation ($\tau_b = -0.926^{**}$, $P < 0.01$), climate change and variability ($\tau_b = -0.924^{**}$, $P < 0.01$), and drought frequency and severity ($\tau_b = -0.924^{**}$, $P < 0.01$).

The analysis of environmental trends was as shown in table 4.

Economic Trends

The total number of livestock owned in the study area was found to have a significant positive trend ($Z = 3.11$, $P < 0.01$). The total number of livestock was found to have a significant positive correlation with access to extension services ($\tau_b = 0.638^{**}$, $P < 0.01$), access to veterinary services ($\tau_b = 0.638^{**}$, $P < 0.01$), human population ($\tau_b =$

0.723**, P<0.01), human population ($\tau_b = 0.690**$, P<0.01), in-migration ($\tau_b = 0.734**$, P<0.01), and demand for livestock and livestock products ($\tau_b = 0.678**$, P<0.01). Besides the total number of livestock had a significant negative correlation with livestock disease incidences ($\tau_b = -0.536*$, P<0.05). The number of livestock owned per household had a significant negative trend ($Z = -3.83$, P<0.001). The number of livestock per household was found to have a significant positive correlation with pasture availability ($\tau_b = 0.895**$, P<0.01), water availability ($\tau_b = 0.878**$, P<0.01), rainfall amount ($\tau_b = 0.876**$, P<0.01), land management ($\tau_b = 0.720**$, P<0.01), effectiveness of customary governance systems ($\tau_b = 0.848**$, P<0.01), and land adequacy ($\tau_b = 0.878**$, P<0.01). Also, the number of livestock per household had a significant positive correlation with livestock mobility ($\tau_b = 0.885**$, P<0.01), security ($\tau_b = 0.896**$, P<0.01), and observation of cultural practices ($\tau_b = 0.869**$, P<0.01). Contrarily, the number of livestock per household was found to have a significant negative correlation with land degradation ($\tau_b = -0.893**$, P<0.01), drought frequency and severity ($\tau_b = -0.891**$, P<0.01), climate change and variability ($\tau_b = -0.891**$, P<0.01), and conflicts ($\tau_b = -0.906**$, P<0.01). In addition, the number of livestock per household had a significant negative correlation with livelihood diversification ($\tau_b = -0.895**$, P<0.01), land privatization ($\tau_b = -0.850**$, P<0.01), farming activities ($\tau_b = -0.935**$, P<0.01), and the establishment of nature conservation reserves ($\tau_b = -0.920**$, P<0.01).

Table 4: Analysis of environmental trends

#	Trend	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010s	Mann-Kendall (Z) Test	Sig
1	Climate change and variability	3	3	4	4	4	5	5	7	7	8	9	9	4.05	***
2	Rainfall amount	9	9	9	9	9	9	8	7	7	6	5	4	-3.62	***
3	Drought frequency and severity	3	3	4	4	4	5	5	7	7	8	9	9	4.05	***
4	Land degradation	1	1	2	2	2	3	4	5	7	7	1	1	4.17	***
5	Invasive species prevalence	1	1	2	2	3	3	4	5	6	7	8	9	4.28	***
6	Stream flows	9	8	8	7	6	5	5	4	4	3	2	1	-4.28	***
7	Water availability	9	8	8	7	6	5	5	4	4	3	2	1	-4.28	***
8	Tree cover	10	9	9	8	7	6	5	5	4	4	3	3	-4.22	***
9	Pasture availability	9	9	8	7	6	6	5	4	4	3	2	1	-4.28	***
10	Herbs availability	10	10	9	9	8	7	6	6	5	5	4	3	-4.22	***
11	Wildlife abundance	10	9	8	7	6	6	5	4	4	3	3	2	-4.28	***
12	Bees abundance	10	10	10	9	8	8	7	6	6	5	5	4	-4.11	***

Incidences of livestock diseases were found to be declining significantly ($Z = -3.41$, P<0.001). Incidences of livestock diseases had a significant negative correlation with access to extension services ($\tau_b = -0.843**$, P<0.01), access to veterinary services ($\tau_b = -0.843**$, P<0.01), access to education ($\tau_b = -0.818**$, P<0.01), access to information services ($\tau_b = -0.815**$, P<0.01), and access to government services ($\tau_b = -0.815**$, P<0.01).

The study found the demand for livestock and livestock products had a significant positive trend ($Z = 4.17$, P<0.001). The demand for livestock and livestock products

was found to have a significant positive correlation with human population ($\tau_b = 0.943^{**}$, $P < 0.01$), in-migration ($\tau_b = 0.952^{**}$, $P < 0.01$), urban growth ($\tau_b = 0.952^{**}$, $P < 0.01$), access to markets ($\tau_b = 0.972^{**}$, $P < 0.01$), and livelihood diversification ($\tau_b = 0.952^{**}$, $P < 0.01$). Additionally, the demand for livestock and livestock products was found to have a significant positive correlation with employment opportunities ($\tau_b = 0.950^{**}$, $P < 0.01$), infrastructure development ($\tau_b = 0.917^{**}$, $P < 0.01$), access to transport services ($\tau_b = 0.941^{**}$, $P < 0.01$), and access to communication services ($\tau_b = 0.924^{**}$, $P < 0.01$). The demand for livestock and livestock products was found to have a significant negative correlation with livestock disease incidences ($\tau_b = -0.811^{**}$, $P < 0.01$).

There was a significant positive trend in the diversification of livelihoods in the study area ($Z = 4.28$, $P < 0.001$). The study found the livelihoods diversification had a significant positive correlation with human population ($\tau_b = 0.992^{**}$, $P < 0.01$), in-migration ($\tau_b = 0.952^{**}$, $P < 0.01$), outmigration ($\tau_b = 0.935^{**}$, $P < 0.01$), food diversification ($\tau_b = 0.968^{**}$, $P < 0.01$), urban growth ($\tau_b = 0.984^{**}$, $P < 0.01$), access to markets ($\tau_b = 0.960^{**}$, $P < 0.01$), and access to credit ($\tau_b = 0.891^{**}$, $P < 0.01$). Still, livelihoods diversification had a significant positive correlation with access to formal education ($\tau_b = 0.943^{**}$, $P < 0.01$), employment opportunities ($\tau_b = 0.900^{**}$, $P < 0.01$), women empowerment ($\tau_b = 0.900^{**}$, $P < 0.01$), number of female-headed households ($\tau_b = 0.900^{**}$, $P < 0.01$), and conflicts ($\tau_b = 0.818^{**}$, $P < 0.01$). Further, the study found that livelihoods diversification had a significant positive correlation with access to government services ($\tau_b = 1.000^{**}$, $P < 0.01$), infrastructure development ($\tau_b = 0.968^{**}$, $P < 0.01$), access to transport services ($\tau_b = 0.926^{**}$, $P < 0.01$), access to communication services ($\tau_b = 0.943^{**}$, $P < 0.01$), and access to information ($\tau_b = 1.000^{**}$, $P < 0.01$). Also, livelihoods diversification had a significant positive correlation with drought frequency and severity ($\tau_b = 0.951^{**}$, $P < 0.01$), climate change and variability ($\tau_b = 0.951^{**}$, $P < 0.01$), and land degradation ($\tau_b = 0.968^{**}$, $P < 0.01$). On the other hand, livelihood diversification had a significant negative correlation with observation of cultural practices ($\tau_b = -0.944^{**}$, $P < 0.01$), security ($\tau_b = -0.789^{**}$, $P < 0.01$), food security ($\tau_b = -0.901^{**}$, $P < 0.01$), land adequacy ($\tau_b = -0.952^{**}$, $P < 0.01$), and number of livestock per household ($\tau_b = -0.895^{**}$, $P < 0.01$).

Honey production in the study area has declined significantly over time ($Z = -4.28$, $P < 0.001$). The study found that honey production had a significant positive correlation with bee abundance ($\tau_b = 0.943^{**}$, $P < 0.01$), tree cover ($\tau_b = 0.960^{**}$, $P < 0.01$), land adequacy ($\tau_b = 0.952^{**}$, $P < 0.01$), rainfall amount ($\tau_b = 0.873^{**}$, $P < 0.01$), effectiveness of land management ($\tau_b = 0.806^{**}$, $P < 0.01$), effectiveness of customary land governance ($\tau_b = 0.943^{**}$, $P < 0.01$), and observation of cultural practices ($\tau_b = 0.944^{**}$, $P < 0.01$). On the other hand, honey production had a significant negative correlation with land degradation ($\tau_b = -0.968^{**}$, $P < 0.01$), climate change and variability ($\tau_b = -0.935^{**}$, $P < 0.01$), drought frequency and severity ($\tau_b = -0.935^{**}$, $P < 0.01$), and human population ($\tau_b = -0.992^{**}$, $P < 0.01$). The demand for honey had a significant positive trend ($Z = 4.28$, $P < 0.001$). The study found that the demand for honey had a significant positive correlation with human population ($\tau_b = 0.992^{**}$, $P < 0.01$), in-migration ($\tau_b = 0.952^{**}$, $P < 0.01$), urban growth ($\tau_b = 0.984^{**}$, $P < 0.01$), and employment opportunities ($\tau_b = 0.900^{**}$, $P < 0.01$). Further, the demand for honey had a significant positive correlation with access to markets ($\tau_b = 0.960^{**}$, $P < 0.01$), access to transport services ($\tau_b = 0.926^{**}$, $P < 0.01$),

access to communication services ($\tau_b = 0.926^{**}$, $P < 0.01$), and access to information services ($\tau_b = 0.984^{**}$, $P < 0.01$). The demand for honey had a significant negative correlation with honey production ($\tau_b = -0.990^{**}$, $P < 0.01$).

The demand for herbal products had a significant positive trend ($Z = 4.06$, $P < 0.001$). The demand for herbs products was found to have a significant positive correlation with human population ($\tau_b = 0.942^{**}$, $P < 0.01$), in-migration ($\tau_b = 0.951^{**}$, $P < 0.01$), urban growth ($\tau_b = 0.951^{**}$, $P < 0.01$), and employment opportunities ($\tau_b = 0.930^{**}$, $P < 0.01$). Further, the demand for herbs products had a significant positive correlation with access to markets ($\tau_b = 0.976^{**}$, $P < 0.01$), access to transport services ($\tau_b = 0.974^{**}$, $P < 0.01$), access to communication services ($\tau_b = 0.922^{**}$, $P < 0.01$), and access to information services ($\tau_b = 0.951^{**}$, $P < 0.01$). The demand for herb products had a significant negative correlation with the availability of herbs ($\tau_b = -0.947^{**}$, $P < 0.01$).

The demand for wood tree products had a significant positive trend ($Z = 4.17$, $P < 0.001$). The demand for wood tree products was found to have a significant positive correlation with human population ($\tau_b = 0.952^{**}$, $P < 0.01$), in-migration ($\tau_b = 0.976^{**}$, $P < 0.01$), urban growth ($\tau_b = 0.976^{**}$, $P < 0.01$), and employment opportunities ($\tau_b = 0.942^{**}$, $P < 0.01$). Further, the demand for wood tree products had a significant positive correlation with access to markets ($\tau_b = 1.000^{**}$, $P < 0.01$), infrastructure development ($\tau_b = 0.926^{**}$, $P < 0.01$), access to transport services ($\tau_b = 0.950^{**}$, $P < 0.01$), access to communication services ($\tau_b = 0.933^{**}$, $P < 0.01$), and access to information services ($\tau_b = 0.928^{**}$, $P < 0.01$), and access to communication services ($\tau_b = 0.933^{**}$, $P < 0.01$). The demand for wood tree products had a significant negative correlation with the tree cover ($\tau_b = -0.976^{**}$, $P < 0.01$).

A significant positive trend was also observed as appertains to ecotourism activities in the study area ($Z = 3.95$, $P < 0.001$). Ecotourism activities had a significant positive correlation with access to government services ($\tau_b = 0.855^{**}$, $P < 0.01$), infrastructure development ($\tau_b = 0.893^{**}$, $P < 0.01$), access to information services ($\tau_b = 0.866^{**}$, $P < 0.01$), and access to transport services ($\tau_b = 0.849^{**}$, $P < 0.01$). Besides, ecotourism activities were found to have a significant positive correlation with livelihood diversification ($\tau_b = 0.928^{**}$, $P < 0.01$), urban growth ($\tau_b = 0.912^{**}$, $P < 0.01$), access to markets ($\tau_b = 0.887^{**}$, $P < 0.01$), and establishment of nature conservation areas ($\tau_b = 0.937^{**}$, $P < 0.01$). Ecotourism activities had a significant negative correlation with livestock holding per household ($\tau_b = -0.853^{**}$, $P < 0.01$).

Sand harvesting was also found to have a significant positive trend ($Z = 4.34$, $P < 0.001$). The study revealed that sand harvesting has a significant positive correlation with population growth ($\tau_b = 0.984^{**}$, $P < 0.01$), urban growth ($\tau_b = 0.992^{**}$, $P < 0.01$), access to markets ($\tau_b = 0.968^{**}$, $P < 0.01$), and access to government services ($\tau_b = 0.910^{**}$, $P < 0.01$). Additionally, sand harvesting had a significant positive correlation with livelihood diversification ($\tau_b = 0.992^{**}$, $P < 0.01$), infrastructure development ($\tau_b = 0.960^{**}$, $P < 0.01$), access to information ($\tau_b = 0.992^{**}$, $P < 0.01$), access to communication services ($\tau_b = 0.935^{**}$, $P < 0.01$), and access to transport services ($\tau_b = 0.919^{**}$, $P < 0.01$). Sand harvesting had a significant negative correlation with livestock holding per household ($\tau_b = -0.904^{**}$, $P < 0.01$).

Employment opportunities in the study were found to have increased significantly ($Z = 3.83$, $P<0.001$). The study found out that employment opportunities had a significant positive correlation with formal education ($\tau_b = 0.940^{**}$, $P<0.01$), access to government services ($\tau_b = 0.889^{**}$, $P<0.01$), urban growth ($\tau_b = 0.917^{**}$, $P<0.01$), access to markets ($\tau_b = 0.942^{**}$, $P<0.01$), and livelihood diversification ($\tau_b = 0.900^{**}$, $P<0.01$). Moreover, employment opportunities had a significant positive correlation with infrastructure development ($\tau_b = 0.895^{**}$, $P<0.01$), information access ($\tau_b = 0.900^{**}$, $P<0.01$), sand harvesting ($\tau_b = 0.910^{**}$, $P<0.01$), ecotourism activities ($\tau_b = 0.856^{**}$, $P<0.01$), and establishment of nature conservation reserves ($\tau_b = 0.927^{**}$, $P<0.01$).

Access to credit was found to be increasing significantly over time ($Z = 3.62$, $P<0.001$). The study revealed that access to credit had a significant positive correlation with access to government services ($\tau_b = 0.913^{**}$, $P<0.01$), livelihood diversification ($\tau_b = 0.891^{**}$, $P<0.01$), urban growth ($\tau_b = 0.873^{**}$, $P<0.01$), formal education ($\tau_b = 0.876^{**}$, $P<0.01$), and access to markets ($\tau_b = 0.880^{**}$, $P<0.01$). Besides access to credit had a significant positive correlation with women empowerment ($\tau_b = 0.932^{**}$, $P<0.01$), access to information services ($\tau_b = 0.891^{**}$, $P<0.01$), access to transport services ($\tau_b = 0.869^{**}$, $P<0.01$), and access to communication services ($\tau_b = 0.907^{**}$, $P<0.01$).

The study found the practice of farming activities to have a significant positive trend ($Z = 4.23$, $P<0.001$). The practice of farming activities was found to have a significant positive correlation with livelihood diversification ($\tau_b = 0.960^{**}$, $P<0.01$), food diversity ($\tau_b = 0.960^{**}$, $P<0.01$), in-migration ($\tau_b = 0.960^{**}$, $P<0.01$), land privatization ($\tau_b = 0.918^{**}$, $P<0.01$), urban growth ($\tau_b = 0.960^{**}$, $P<0.01$), human population ($\tau_b = 0.968^{**}$, $P<0.01$), infrastructure development ($\tau_b = 0.926^{**}$, $P<0.01$), and information access ($\tau_b = 0.960^{**}$, $P<0.01$). Moreover, farming activities had a significant negative correlation with number of livestock per household ($\tau_b = -0.935^{**}$, $P<0.01$), livestock mobility ($\tau_b = -0.952^{**}$, $P<0.01$), food security ($\tau_b = -0.908^{**}$, $P<0.01$), and observation of cultural practices ($\tau_b = -0.935^{**}$, $P<0.01$).

Access to wood fuel was also found to be decreasing significantly ($Z = -4.05$, $P<0.001$). Access to firewood was found to have a significant positive correlation with tree cover ($\tau_b = 0.976^{**}$, $P<0.01$), effectiveness of land management ($\tau_b = 0.797^{**}$, $P<0.01$), and land adequacy ($\tau_b = 0.935^{**}$, $P<0.01$). Besides, access to wood fuel had a significant negative correlation with ($\tau_b = -0.950^{**}$, $P<0.01$), human population ($\tau_b = -0.942^{**}$, $P<0.01$), urban growth ($\tau_b = -0.951^{**}$, $P<0.01$), privatization of land ($\tau_b = -0.908^{**}$, $P<0.01$), farming activities ($\tau_b = -0.976^{**}$, $P<0.01$), and establishment of nature conservation reserves ($\tau_b = -0.960^{**}$, $P<0.01$).

Infrastructure development was found to have a significant positive trend ($Z = 4.05$, $P<0.001$). The study revealed that infrastructure development had a significant positive correlation with access to government services ($\tau_b = 0.858^{**}$, $P<0.01$), urban growth ($\tau_b = 0.951^{**}$, $P<0.01$), access to markets ($\tau_b = 0.926^{**}$, $P<0.01$), population growth ($\tau_b = 0.959^{**}$, $P<0.01$), and demand for livestock and livestock products ($\tau_b = 0.917^{**}$, $P<0.01$). Additionally, infrastructure development had a significant positive correlation with sand harvesting ($\tau_b = 0.960^{**}$, $P<0.01$), ecotourism activities ($\tau_b = 0.893^{**}$, $P<0.01$), farming activities ($\tau_b = 0.926^{**}$, $P<0.01$), and establishment of

nature conservation reserves ($\tau_b = 0.944^{**}$, $P < 0.01$). Infrastructure development had a non-significant positive correlation with community involvement in decision-making ($\tau_b = 0.310$, $P > 0.05$).

Access to transport services was found to have a significant increasing trend ($Z = 3.88$, $P < 0.001$). Access to transport services was found to have a significant positive correlation with access to government services ($\tau_b = 0.899^{**}$, $P < 0.01$), infrastructure development ($\tau_b = 0.905^{**}$, $P < 0.01$), human population ($\tau_b = -0.943^{**}$, $P < 0.01$), and urban growth ($\tau_b = 0.952^{**}$, $P < 0.01$). Moreover, access to transport services had a significant positive correlation with demand for livestock and livestock products ($\tau_b = 0.941^{**}$, $P < 0.01$), access to markets ($\tau_b = 0.950^{**}$, $P < 0.01$), sand harvesting ($\tau_b = 0.919^{**}$, $P < 0.01$), and ecotourism ($\tau_b = 0.849^{**}$, $P < 0.01$). Access to transport services had a non-significant positive correlation with community involvement in decision-making ($\tau_b = 0.407$, $P > 0.05$).

Access to communication services was also found to have a significant increasing trend ($Z = 3.90$, $P < 0.001$). The study revealed that access to communication services had a significant positive correlation with access to government services ($\tau_b = 0.899^{**}$, $P < 0.01$), infrastructure development ($\tau_b = 0.957^{**}$, $P < 0.01$), access to markets ($\tau_b = 0.933^{**}$, $P < 0.01$), access to information ($\tau_b = 0.943^{**}$, $P < 0.01$), access to formal education ($\tau_b = 0.914^{**}$, $P < 0.01$), urban growth ($\tau_b = 0.926^{**}$, $P < 0.01$), and human population ($\tau_b = 0.933^{**}$, $P < 0.01$). Further, access to communication services had a significant positive correlation with community involvement in decision-making ($\tau_b = 0.407$, $P > 0.05$).

Access to information services such as electronic media was found to have a significant positive trend ($Z = 4.28$, $P < 0.001$). The study revealed that access to information services had a significant positive correlation with access to government services ($\tau_b = 0.900^{**}$, $P < 0.01$), access to education ($\tau_b = 0.943^{**}$, $P < 0.01$), infrastructure development ($\tau_b = 0.968^{**}$, $P < 0.01$), access to communication ($\tau_b = 0.943^{**}$, $P < 0.01$), access to extension services ($\tau_b = 0.886^{**}$, $P < 0.01$), urban growth ($\tau_b = 0.984^{**}$, $P < 0.01$), and access to transport services ($\tau_b = 0.926^{**}$, $P < 0.01$).

Access to markets has also increased significantly ($Z = 4.28$, $P < 0.001$). A significant positive correlation was found between market access and access to government services ($\tau_b = 0.925^{**}$, $P < 0.01$), infrastructure development ($\tau_b = 0.926^{**}$, $P < 0.01$), access to information services ($\tau_b = 0.876^{**}$, $P < 0.01$), access to communication services ($\tau_b = 0.933^{**}$, $P < 0.01$), access to transport services ($\tau_b = 0.950^{**}$, $P < 0.01$), human population ($\tau_b = 0.952^{**}$, $P < 0.01$), employment opportunities ($\tau_b = 0.942^{**}$, $P < 0.01$), and urban growth ($\tau_b = 0.976^{**}$, $P < 0.01$).

Urban growth had a significant positive trend ($Z = 4.28$, $P < 0.001$). Urban growth was found to have a significant positive correlation with human population ($\tau_b = 0.976^{**}$, $P < 0.01$), in-migration ($\tau_b = 0.968^{**}$, $P < 0.01$), access to government services ($\tau_b = 0.917^{**}$, $P < 0.01$), education ($\tau_b = 0.960^{**}$, $P < 0.01$), employment opportunities ($\tau_b = 0.917^{**}$, $P < 0.01$), and livelihood diversification ($\tau_b = 0.984^{**}$, $P < 0.01$). Furthermore, urban growth had a significant positive correlation with ($\tau_b = 0.943^{**}$, $P < 0.01$), access to transport services ($\tau_b = 0.926^{**}$, $P < 0.01$), access to communication services ($\tau_b = 0.926^{**}$, $P < 0.01$), ecotourism ($\tau_b = 0.912^{**}$, $P < 0.01$), sand harvesting ($\tau_b = 0.926^{**}$, $P < 0.01$), and community involvement in decision-making ($\tau_b = 0.407$, $P > 0.05$).

0.992**, P<0.01), demand for livestock and livestock products ($\tau_b = 0.952**$, P<0.01), and conflict incidences ($\tau_b = 0.818**$, P<0.01). Urban growth, on the other hand, was found to have a significant negative correlation with livestock mobility ($\tau_b = -0.944**$, P<0.01), security ($\tau_b = -0.806**$, P<0.01), land adequacy ($\tau_b = -0.952**$, P<0.01), and observation of cultural practices ($\tau_b = -0.952**$, P<0.01).

The adequacy of land in the study was found to be decreasing significantly over time ($Z = -4.28$, P<0.001). The study revealed that land adequacy had a significant positive correlation with livestock mobility ($\tau_b = 0.944**$, P<0.01), effectiveness of land management ($\tau_b = 0.772**$, P<0.01), effectiveness of customary governance systems ($\tau_b = 0.910**$, P<0.01), land tenure security ($\tau_b = 0.620*$, P<0.05), and security ($\tau_b = 0.754**$, P<0.01). To the contrary, the study established that land adequacy had a significant negative correlation with human population ($\tau_b = -0.944**$, P<0.01), in-migration ($\tau_b = -0.984**$, P<0.01), urban growth ($\tau_b = -0.952**$, P<0.01), access to markets ($\tau_b = -0.960**$, P<0.01), infrastructure development ($\tau_b = -0.951**$, P<0.01), and livestock numbers ($\tau_b = -0.768**$, P<0.01). Also, land adequacy had a significant negative correlation with conflicts ($\tau_b = -0.784**$, P<0.01), farming activities ($\tau_b = -0.960**$, P<0.01), privatization of land ($\tau_b = -0.960**$, P<0.01), and establishment of nature conservation reserves ($\tau_b = -0.961**$, P<0.01).

The analysis of economic trends was as shown in table 5.

Discussion

The study identified and analyzed various socioecological trends among the pastoralist community in Laikipia County. The human population was found to be increasing over time. This was because people are attracted and migrated to the pastoral area due to the improved access to government services, formal education, and health services. Infrastructural development, improved access to transport and communication services, and information has also attracted people to move to and settle in the area. Goldsmith (2012) observed that access to the internet, mobile telephony, and satellite television are making pastoral areas more attractive to people, including professionals. The growth of urban centers and access to markets has also attracted people to the area. The decline in pastoral mobility and, hence, sedentarization has also caused an increase in population as people are concentrated in one area. Likewise, pastoralists from neighboring drier pastoral areas have been moving and settling in the area in search of pasture, especially during long drought seasons. The reduction in mortality rates, which is partly due to improvements in health services, has also led to an increase in the human population.

Urban centers in the study area were growing as a result of the growth of the human population, decline in pastoral mobility and attraction to spatially fixed-point security and social services that have changed and concentrated the settlement patterns. ODI (2009) observed that population growth and the changes in population distribution in Arid and Semi-arid Lands have led to the emergence and growth of urban areas. Similarly, the improved access to markets and factors that create an enabling environment for business activities in the urban centers such as transport and communication services have also contributed to their growth. The change of

pastoralists from traditional to modern culture and livelihood diversification has led to the adoption of a modern way of life that is urban-oriented. The declining availability of land and other pastoral resources and the reduction in livestock holding per household has also driven the change in livelihoods leading to the adoption of urban-based livelihoods and, hence, the growth of urban areas. In addition, ODI (2009) found that the factors influencing the formation of urban and peri-urban areas in pastoralist areas include conflicts, insecurity, appropriation of land by non-pastoralists, and development activities.

Table 5: Analysis of economic trends

#	Trend	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010s	Mann-Kendall (Z) Test	Sig
1	Total number of livestock	2	4	5	5	6	6	6	7	5	8	6	9	3.11	**
2	Number of livestock per household	7	8	8	7	7	6	5	5	4	3	2	2	-3.83	***
3	Livestock disease incidences	10	9	9	9	8	8	8	8	7	5	4	6	-3.41	***
4	Demand for livestock and livestock products	2	2	2	3	3	4	5	6	7	8	9	9	4.17	***
5	Livelihood diversification	1	1	2	2	3	3	4	5	6	7	8	9	4.28	***
6	Honey production	10	9	8	8	7	7	6	5	4	4	3	2	-4.28	***
7	Demand for honey	1	1	2	2	3	4	5	6	7	7	8	9	4.28	***
8	Demand for herb products	3	3	3	4	4	4	5	5	6	7	8	9	4.06	***
9	Demand for wood tree products	2	2	2	3	3	4	5	5	6	7	8	9	4.17	***
10	Ecotourism	0	0	1	1	2	2	3	4	5	6	7	5	3.95	***
11	Sand harvesting	0	0	1	1	2	3	4	5	6	7	8	9	4.34	***
12	Employment opportunities	1	1	1	2	2	3	3	3	3	4	5	5	3.83	***
13	Credit access	1	1	1	1	1	1	2	3	3	4	5	6	3.62	***
14	Farming activities	1	1	1	2	3	4	5	6	7	7	8	9	4.23	***
15	Access to wood fuel	10	10	10	9	9	8	7	7	6	6	5	5	-4.05	***
16	Infrastructure development	1	1	2	2	3	3	3	4	4	5	5	6	4.05	***
17	Access to transport services	1	1	1	2	2	2	3	3	4	4	4	5	3.88	***
18	Access to communication services	1	1	1	1	2	2	2	3	3	4	5	6	3.90	***
19	Access to information e.g. electronic media	1	1	2	2	3	3	4	5	6	7	8	9	4.28	***
20	Access to markets	1	1	1	2	3	4	5	5	6	7	8	9	4.23	***
21	Growth of urban areas	1	1	2	2	3	4	5	5	6	7	8	9	4.28	***
22	Land adequacy	10	9	9	8	7	6	5	4	4	3	3	2	-4.28	***

Food security in the study area was found to be on a downward trend. This was due to the declining number of livestock per household and, hence, the lack of adequate herds to sustain livelihoods in most households. The declining social cohesion has negatively affected social networks and, thus, degraded the mutual mechanisms of reciprocity based on which pastoral communities supported each other during crises such as famine. Also, IPCC (2019) noted that climate change is negatively affecting food security in pastoral systems of Africa's drylands due to direct or indirect effects on crop and livestock production. Moreover, Gelan, Getahun and Beyene (2017) pointed out that pastoralists are facing frequent food security problems due to the scarcity of pastoral resources and ecological stress.

The study, however, found food diversity to be increasing over time. This was due to food insecurity that has caused the affected pastoralists to seek and adopt alternative foods and food sources. The increasing access to markets and thus trade and supply of food products, especially from non-pastoral areas, has also driven the adoption of other food diets. The changing lifestyles have also contributed to the adoption of other food diets. Moreover, greater access to formal education, information, and health services means that people are learning and appreciating the value and health benefits of diverse food diets. According to FAO (2017), urbanization has been accompanied by a transition of dietary patterns and has a great impact on food systems. Besides, Gebremichael and Asfaw (2019) noted that food choices in communities are influenced by market access and the knowledge of nutritious and healthy foods. Pastoral diets are also changing as the effects of climate change and environmental degradation make it increasingly difficult for pastoral households to subsist on a purely pastoral economy due to declining livestock ownership (Krätli and Swift, 2014; Njoka *et al.*, 2016).

The observed positive trend in women's empowerment is driven by factors that have exposed pastoral women to the outside world and taught them to be independent. These factors include access to formal education and information, in-migration of people from other areas, and outmigration to other areas. The improved access to government services and, hence, better implementation of policy provisions and initiatives that promote gender equity in the area has also increased women's empowerment. Besides, livelihood diversification has created economic opportunities that enable women to pursue independent livelihoods leading to greater financial independence and space for decision-making. This has been supported by improved access to credit services which enables women to access financial capital. According to Goldsmith (2012), pastoralist women are responding to emerging opportunities and setting up new income-generating activities, particularly around service provision and trade. The increase in community participation in decision-making also translated into greater women empowerment.

The continued decline in social cohesion in the study area is concordant with the Government of Kenya's (2012) observation that pastoralists are caught up in a process of social differentiation whereby the social fabric that held communities together is breaking down. Social cohesion is declining as the observation of cultural practices that acted as points and means for interaction and, thus, contributed to the establishment of the community's social fabric diminishes. The declining trend in moral values also means that the ethics that guided people to coexist have been eroded over time. The declining social cohesion is also caused by factors that cause pastoralists to change their communal lifestyles to become more capitalistic and individualistic including urban growth, access to markets, livelihood diversification, and land privatization. The resultant commodification of pastoral production has enhanced the focus on individual profit as opposed to collective gain and hence the degradation of social cohesion. According to Galvin (2008), the pursuit of livelihood diversification can lead to social fragmentation as individuals pursue disparate goals and, thus, acquire different viewpoints based on their experiences. The commodification of land resources and livestock is fragmenting pastoral communal systems as pastoralists develop a greater preference for individual profit than collective gain (Galvin, 2008; Reid, Fernandez-Gimenez and Galvin, 2014).

The study revealed that income inequality was increasing over time. This agrees with Njoka *et al.* (2016) who observed that the gap between the rich and the poor pastoral communities continues to widen as a few individuals get richer while many pastoral households are trapped in a vicious cycle of poverty. While the group of poor pastoralists has grown bigger, that of well-off pastoralists has remained typically small (FSAU, 2001) as livestock ownership in pastoral areas is increasingly consolidated in the hands of a few wealthy people who are mostly outsiders (De Haan *et al.*, 2016). Therefore, some households have been left out or are moving out of pastoralism in the backdrop of the inexistence of viable alternatives as a few individuals increase their production. Similarly, income inequality has increased as the social capital, which enabled mutual sharing in pastoral communities, and, thus, reduced disparities between community members. The unequal accumulation of livestock across domestic groups in the past was offset by collective ties across age sets (Bonte, 1981; Rigby, 1992). Changing land tenure, especially through land privatization and hence unequal accumulation of rangeland resources has also caused income inequalities. Moreover, as pastoralists diversify their livelihoods, income inequalities could result due to unequal access to knowledge, skills, and capital, which cause some households to fair better than others.

The downward trend in security was due to an increase in unethical and criminal activities as moral values decline. The weakening of customary governance systems that were keys to instilling moral values, and law and order in the community has led to an increase in insecurity. Similarly, conflicts in the area have also increased as security has declined. This has been driven by the scarcity of pastoral resources as demand rises and the existing rangeland resources are degraded. Goldsmith (2012) gathered that conflicts in pastoralist areas are caused by several overlapping factors including high population growth rates, environmental degradation, and insecurity. Correspondingly, the weakening of traditional governance systems that are keys in addressing conflict issues in the community has contributed to the increase in conflict incidences. Moreover, climate change and variability, especially the frequent occurrence of droughts in East Africa's arid and semi-arid areas increase communal conflicts over pastoral resources (Raleigh and Kniveton, 2012; USAID, 2012). The intensification of pastoral conflicts in East Africa is also caused by the increased alienation of pastoral land to other uses, and disruptions of pastoral mobility (Few *et al.*, 2015).

The customary governance systems and land management have diminished as people get more access to government services that are replacing and weakening the role of traditional governance structures. This is largely explained by the process of the colonial and post-independence governments introducing new land tenure and statutory governance systems in pastoralist areas that disrupted and undermined the traditional governance institutions (Kaye-Zwiebel and King, 2014; Basupi, Quinn and Dougill, 2017). Wynants *et al.* (2019) noted that these coercive policies of land use, privatization, sedentarization, exclusion, and marginalization led to a gradual erosion of indigenous social, political, and economic structures. Furthermore, Kaye-Zwiebel and King (2014) gathered that changing governance systems and new resource management institutions challenge the capacity of communities to effectively manage common pool resources.

Moreover, the decline of customary governance systems has been due to cultural erosion as people adopt new ways of life due to the in-migration of new people, access to formal education and information, market access, and urbanization. Besides, the loosening of moral values has led to low respect and recognition of elders and traditional governance structures, especially by the younger generation. The greater incorporation and exposure of pastoral people to western education, national politics, and market economies have resulted in the abandonment of pastoral livelihoods (Thebaud and Batterbury, 2001; Andriansen, 2003). Besides, the erosion of social cohesion and the traditional hierarchical structure within pastoral communities had led to the young generation increasingly feeling much less morally and socially indebted to the older ones (De Haan *et al.*, 2016).

Further, the emerging and accelerating shocks and stresses such as climate change and variability, new land tenure and use regimes, rapid population growth, resource scarcity, insecurity, and conflicts have created new scenarios that disorient, destabilize, and hinder the effectiveness of traditional decision-making structures. These factors also destruct the enabling environment for effective governance. Climate change and variability influence ecosystem dynamics and, thus, exert a major influence on pastoral livelihood strategies and institutions (Galvin *et al.*, 2001). Still, Fratkin (2001) and Catley, Lind and Scoones (2013) construed that population growth, social and economic modernization, and the imposition of statutory land tenure systems have tended to decrease the capacity of customary pastoralist governance and grazing management and restrict the traditional strategies for coping with disturbances such as drought.

The declining adequacy of land was caused by the declining effectiveness of land management mechanisms, which leads to inefficient and unsustainable utilization of the available rangeland resources. Furthermore, the decrease in livestock mobility has meant that pastoralists are mostly confined within their community lands hindering access to alternative grazing lands. This is aggravated by the changing land tenure and land use that have led to the loss of previously pastoral land through privatization and non-pastoral activities such as farming, private ranching, urban growth, infrastructure development, and establishment of wildlife conservation reserves. In addition, there is increasing demand and, hence, pressure on available land due to the growth of the human population and livestock numbers. In Sub-Saharan Africa, competition over land has intensified over the last few decades due to urbanization, agriculture intensification, conservation initiatives, and privatization of communal land through policies that have sought to replace customary communal tenure systems with private liberal property rights (Diao, Magalhaes and Silver, 2019; Kisamba-Mugerwa, Pender and Kato, 2006). This scarcity of land in pastoral areas can be traced back to the colonial and post-colonial times when pastoral communities were systematically excluded from vast areas of land that were repurposed for agriculture, private ranches, conservation areas, and infrastructure development in the name of development (Wynants *et al.*, 2019).

The upward trend in climate change and variability was associated with the increase in drought frequency and severity and a decrease in rainfall amounts. A study by Mizutani *et al.* (2005) in Laikipia revealed that annual rainfall values have progressively reduced over time while droughts have become more frequent and

severe. Moreover, several studies have reported a warming trend in the East Africa region during the last six decades consistent with African and global trends (Christy, Norries and McNider, 2009). The deterioration of local climate conditions was caused by environmental degradation including the declining tree cover and the underlying factors. Nagash (2021) concluded that climate change and variability are a direct consequence of rangeland degradation. In line with this, land degradation in the study was found to be increasing. Land degradation was associated with the observed decrease in stream flows, increase in invasive species, and reduction in tree cover. The degradation of the land was due to the increasing pressure on natural resources due to the growth in human population, land inadequacy, restriction of livestock mobility, and an increase in the total number of livestock. Further, Little (2013) deduced that restrictions on livestock mobility and increased human and livestock densities create pressures on rangelands leading to land degradation. The increasing demand for natural resources such as sand, water, herbs, and wood tree products, and demand for livestock and livestock products hence the urge to maximize production have led to unsustainable utilization resulting in land degradation. Hannam (2018) pointed out that rangelands are subject to over-extraction of woody biomass and water resources due to population growth and hence pressure on resources.

Climate change and variability leading to the occurrence of extreme rainfall events and hence soil erosion, and severe droughts that hinder vegetation growth and favor the proliferation of invasive species have also contributed to land degradation. Further, land degradation has been caused by poor land use practices associated with urban growth and the expansion of farming activities. Njoka *et al.* (2016) noted that the upcoming small towns in pastoralist areas are often poorly planned and result in negative social and environmental repercussions. The declining effectiveness of land management and customary governance systems has led to poor land use practices hence causing land degradation. Moreover, the decline in land tenure security translates into declining certainty in ownership and hence declining commitment to sustainably manage land and natural resources. The Government of Kenya (2003) pointed out that environmental degradation in pastoral areas is largely caused by poor land management practices, failure of the community land tenure system, and erosion of the efficacy of the traditional pastoral management system. Further, WISP (2008) gathered that policies that create space for the involvement of customary institutions in decision-making and local enforcement of rules and regulations over resources have been successful in reversing land degradation in pastoral areas.

The availability of pastoral resources including pasture and water was also observed to be declining. This was due to the diminishing effectiveness of customary governance systems and land management that led to unsustainable use and degradation. Further, higher demand and hence the pressure on pastoral resources due to human and livestock population growth, declining livestock mobility, and land inadequacy have led to a decline in the availability of pastoral resources. Population growth, and land use policies that focus on the sedentarization of pastoral communities continue to cause accelerated pressure on natural resources leading to rangeland resources degradation (Meadows and Hoffman, 2003; Western, Groom and Worden, 2009). Similarly, the deteriorating climatic conditions that have led to a reduction in rainfall amounts and an increase in drought frequency and severity have caused the scarcity of pasture and water resources. Ripkey *et al.* (2021) noted that the high sensitivity of

pastoralists to weather conditions that shape both grazing land and water sources makes them more vulnerable to climate variability. Moreover, climate change, including the changing rainfall patterns and severe recurrent droughts, affects ecosystems directly by causing a shortage of forage and water (Thornton *et al.*, 2006; Kimaro, Mor and Toribio, 2018).

This increase in demand and pressure on available resources, the deteriorating land management, and governance systems, and the deteriorating climate conditions have also caused a decline in the availability of natural resources such as herbs, wood fuel, and wood tree products in the study area. Few *et al.* (2015) noted that extreme climatic conditions and land degradation have caused the decline of biodiversity in the last decades in East Africa. Similarly, they have caused the observed decline in wildlife and bee abundance and honey production. The decline in wildlife abundance is also caused by declining security which has led to an increase in poaching incidences. It is also due to the increase in conflict incidences which include human-wildlife conflicts and hence result in the killing and displacement of wildlife, especially in community lands. Moreover, changing land tenure and use in pastoral areas through the privatization of land and an increase in farming plots, and the resultant fencing activities have affected wildlife due to a reduction in habitats and animal mobility. According to Ongutu *et al.* (2014), wildlife populations in Africa are declining severely due to climate change, rising population pressures, and policy, economic and sociocultural transformations.

In addition, the study found that market access in the study area is increasing. This increase is due to the improvement in access to government services which means there is an improvement in the necessary support services. Besides, the increase in infrastructure development, better access to transport and communication services, and improved access to information have led to an improvement of the mediums of trade, market facilities, and ease of access to market centers and production areas. Urban growth, human population growth, and an increase in employment opportunities have enhanced the consumer base and hence local demand for merchandise and services which translates to greater market access. According to Thornton (2010), changes in the demand for livestock products have historically been largely driven by human population growth, income growth, and urbanization. Furthermore, market access has increased due to the increasing demand for locally produced products, including livestock and livestock products, herbs, honey, and wood tree products. This concurs with Little (2016) who observed that there has been growth in the national and export markets for rangeland bio-products. Furthermore, Thornton (2010) established that the demand for livestock products will nearly double in Sub-Saharan Africa and South Asia from 200 Kcal per person per day in 2000 to around 400 Kcal per person per day in 2050.

The increasing diversification of pastoralists' livelihoods that was observed in the study area is caused by the declining number of livestock per household which has led to livestock-poor households adopting alternative income-generating activities to survive. Also, the scarcity of land and natural resources due to the increasing population pressure, restricted livestock mobility, and land degradation has necessitated diversification to alternative livelihoods. Diversification is driven by shrinking rangeland resources (Seno and Shaw, 2002; Okello, 2005), declining per

capita livestock wealth, and changing lifestyles (Western and Nightingale, 2003; Homewood, 2009). Pastoralists have also diversified their livelihoods to build their resilience to deteriorating climatic conditions and food insecurity. Asrvor (2017) found that a decrease in rainfall led to an increase in livelihood diversification.

Change in local lifestyles due to various underlying factors such as cultural erosion, in-migration, urbanization, access to formal education, and access to information has also driven the observed upward trend in livelihood diversification. Additionally, pull factors such as improved access to markets, urban growth, and the growth experienced in other economic activities such as ecotourism and sand harvesting are attracting people to venture into alternative income-generating activities to leverage the resultant opportunities. Improved access to credits has also led to an increase in livelihood diversification by providing the financial capital for the establishment of business enterprises. Gebru, Ichoku and Phil-Eze (2018) found that a household's choice and adoption of livelihood diversification had a positive relationship with access to credit. Likewise, Little (2016) noted that the availability of non-pastoral livelihood options has always been influenced by the presence or absence of urban centers since towns afford trading opportunities and the chance to engage in the cash economy.

The growth of non-livestock economic activities such as sand harvesting and ecotourism was driven by the improvement of the needed support infrastructure and services such as communication, transport, information, and government services. Moreover, the establishment of nature conservation reserves has driven the growth in ecotourism activities since they constitute the sector's main product. Infrastructure development, increased settlement, and growth of urban centers have led to an increase in the demand for sand and hence increased sand harvesting. The growth of these non-livestock economic activities has also been caused by the reduction in the number of livestock per household and hence the need for livelihood diversification. This is in agreement with Reid, Fernandez-Gimenez and Galvin (2014) who established that the reduction of income from livestock and its failure to satisfy the growing needs of pastoralist families had caused many of them to diversify their livelihoods by engaging in ecotourism and mining activities.

The decline in livestock mobility was due to a change in land tenure and use that led to land fragmentation and reduced the grazing land that is accessible to pastoralists. The changes in land tenure and use include land privatization, encroachment of farming onto pastoral areas, the establishment of nature conservation reserves, and infrastructure development. The reduction of the available rangeland due to land divisions and the influx of small-scale farmers into pastoral areas have caused sedentarization among previously mobile herders in Laikipia (Boles *et al.*, 2019). Moreover, Herbert and Birch (2022) noted that livestock mobility has been impeded by competition for land that has been caused by the conversion of rangelands to other uses, an agrarian bias in policymaking, environmental challenges, and population growth. The structures and systems that governed pastoral mobility have also diminished as shown by the negative trend in the effectiveness of customary governance systems, land management, and observation of cultural practices. Additionally, the decline of social cohesion has led to the weakening of mutual sharing mechanisms between communities, yet they were the basis of pastoral mobility.

Rising insecurity and conflicts have reduced the accessibility of vast areas of the remaining pastoral rangelands and thus hindered mobility as pastoralists prefer to live near areas that have security services since they are mainly centralized. Likewise, ODI (2009) pointed out that sedentarization in pastoral areas is taking place due to the alienation of pastoral land, conflicts, and insecurity which have rendered some areas inaccessible and caused a decline in rangeland resources. Pastoralists are also becoming more sedentary as they adopt urban lifestyles, diversify to non-pastoral livelihoods, and align their settlements to the fixed-point provision of social services. Furthermore, sedentarization is taking place due to changes in production and marketing priorities (Herbert and Birch, 2022), the growing trading centers that are becoming an attraction to pastoral drop-outs looking for non-livestock livelihood options, and the provision of social services at fixed locations (Njoka *et al.*, 2016). The deteriorating climatic conditions, land degradation, and scarcity of pastoral resources have also caused pastoralists to adopt more sedentary lifestyles as they respond by adopting non-pastoral income-generating activities. According to (FAO, 2001), social, political, and environmental pressures from climate change, population pressure, and land use in East Africa have catalyzed the process of sedentarization.

The study found that the total number of all types of livestock raised in the area is increasing over time. This is due to human population growth and hence the number of livestock owners and livestock owned. The improvements in access to extension and veterinary services have improved livestock husbandry and control of livestock diseases and hence the total number of livestock. According to Thornton (2010), developments in breeding, nutrition, and animal health increase the potential for livestock production. The increasing demand for livestock and livestock products has also caused an increase in livestock numbers as people strive to maximize production to take advantage of the improved market. Besides, Thornton (2010) established that the production response to increasing demand for livestock and livestock products in different livestock systems has been associated with increases in livestock numbers.

Nevertheless, a downward trend was found as appertains to the number of livestock owned per household. Little *et al.* (2001) and Sandford (2006) observed that the growth in human population in pastoral areas eventually outpaced livestock increases leading to a decline in per capita livestock holding beyond the levels needed for subsistence. This was due to the reduced availability of pastoral resources, including pasture and water, and the underlying factors including land degradation, declining climatic conditions, and population growth. Previous studies also revealed that the decline in the number of livestock per household was caused by human population growth and climate shocks (Begzsuren *et al.*, 2004; Randal, 2008).

The increasing inadequacy of pastoral land due to restricted livestock mobility and its alienation and appropriation through the change in land tenure have also reduced the capacity of households to raise adequate livestock herds. Land fragmentation and expansion of crop cultivation into pastoral areas have led to a reduction of available pastoral resources and weakened the sustainability and resilience of pastoral systems (Olson *et al.*, 2004; Müller-Mahn, Rettberg and Getachew, 2010). Furthermore, Letai and Lind (2013) established that restricted mobility has heavily impacted herd sizes in the East Africa region. The decline in the number of livestock per household has also been caused by the deterioration of the enabling environment for livestock production

due to rising insecurity, conflicts, and poor governance and land management. The adoption of alternative livelihood activities has also led to the raising of smaller herds as people move out of pastoralism.

Conclusion

The study found that major changes have occurred with the pastoral system from the 1910s to the present. These changes include the increase in the local population, which had a profound effect on the demand, and, hence, sustainability in the use of resources. The social fabric has also changed as local people interact with the outside world and receive formal education, hence, adopting new knowledge systems. The changes in the social status have either been good such as the increase women empowerment or detrimental such as the diminishing of social cohesion and moral values in the community. The erosion of the areas traditional governance systems and cultural values had a major impact not only on the social fabric but also on the governance of natural status and hence the ecological status and resource availability. The decline in the local natural resources base has a negative effect on local economic activities status since, especially since pastoral livelihoods are highly dependent and sensitive to the status of the environment.

The change in the land tenure system as new forms of land governance and management were introduced did not only lead to diminishing of access to land by pastoralists but had a main influence on land use. The observed changes in land use have mainly been detrimental due to misalignment of new forms of use with the local eco-climatic conditions. Changes in land use and resource availability has influenced pastoral management as observed by the declining livestock mobility and increasing sedentarization. The worsening climatic conditions have also had a profound influence on pastoral livelihoods as diminishing rainfall has led to scarcity of pasture and water resources in the backdrop of declining land availability. The evolution of pastoral livelihoods in response to the deteriorating socioecological system is best depicted by the observed positive trend in livelihood diversification as pastoralists attempt to cope and adapt to the *status quo* by adopting new livelihood strategies.

The findings of this study will enrich pastoral development planning and policymaking processes. It can be realized by helping identify the drivers and, thus, causes of the deterioration of various aspects of the pastoral socioecological systems including the observed deterioration of governance, and livelihoods and environmental status, galvanizing the right response action to alleviate the situation. The relationships between the trends will not only explain causality, but the strength of these relationships will help in prioritizing the most effective response actions to use in resolving various challenges. Likewise, the study will also help identify the most effective policy interventions to adaptation and to improve the pastoral socioecological systems.

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Authors' Declarations and Essential Ethical Compliances

Author's Contributions (in accordance with ICMJE criteria for authorship)

This article is 100% contributed by the sole author. S/he conceived and designed the research or analysis, collected the data, contributed to data analysis & interpretation, wrote the article, performed critical revision of the article/paper, edited the article, and supervised and administered the field work.

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Research involving human bodies or organs or tissues (Helsinki Declaration)

The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

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The author(s) solemnly declare(s) that this research has not involved any animal subject (body or organs) for experimentation. The research was not based on laboratory experiment involving any kind animal. The contexts of animals not even indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of ARRIVE does not apply in cases of this study or written work.

Research on Indigenous Peoples and/or Traditional Knowledge

The author(s) solemnly declare(s) that this research has involved Indigenous Peoples as participants or respondents. Other contexts of Indigenous Peoples or Indigenous Knowledge, if any, are only indirectly covered, if any, through literature review. Therefore, a sample copy of the prior informed consent (PIC) of the respondents and Self-Declaration in this regard are appended.

Research involving Plants

The author(s) solemnly declare(s) that this research has not involved the plants for experiment or field studies. The contexts of plants are only indirectly covered through literature review. Yet, during this research the author(s) obeyed the principles of the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.

(Optional) Research Involving Local Community Participants (Non-Indigenous)

The author(s) solemnly declare(s) that this research has not directly involved any local community participants or respondents belonging to non-Indigenous peoples. Neither this study involved any child in any form directly. The contexts of different humans, people, populations, men/women/children and ethnic people are only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee

or Authority) or prior informed consent (PIC) of the respondents or Self-Declaration in this regard does not apply in cases of this study or written work.

(Optional) PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)

The author(s) has/have NOT complied with PRISMA standards. It is not relevant in case of this study or written work.

Competing Interests/Conflict of Interest

Author(s) has/have no competing financial, professional, or personal interests from other parties or in publishing this manuscript. There is no conflict of interest with the publisher or the editorial team or the reviewers.

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To see original copy of these declarations signed by Corresponding/First Author (on behalf of other co-authors too), please download associated zip folder [Ethical Declarations] from the published Abstract page accessible through and linked with the DOI: <https://doi.org/10.33002/nr2581.6853.060109>

SELF-DECLARATION FORM

Research on Indigenous Peoples and/or Traditional Knowledge

The nature and extent of community engagement should be determined jointly by the researcher and the relevant community or collective, taking into account the characteristics and protocols of the community and the nature of the research.

If your research involved/involves the Indigenous Peoples as participants or respondents, you should fill in and upload this Self-Declaration and/or Prior Informed Consent (PIC) from the Indigenous Peoples. [Please read carefully <https://grassrootsjournals.org/credibility-compliance.php#Research-Ethics>]

1. Conditions of the Research

1.1 Was or will the research (be) conducted on (an) Indigenous land, including reserve, settlement, and land governed under a self-government rule/agreement or?

Yes/No

1.2 Did/does any of the criteria for participation include membership in an Indigenous community, group of communities, or organization, including urban Indigenous populations?

Yes/ No.

1.3 Did/does the research seek inputs from participants (members of the Indigenous community) regarding a community's cultural heritage, artifacts, traditional knowledge, biocultural or biological resources or unique characteristics/practices?

Yes/No

1.4 Did/will Aboriginal identity or membership in an Indigenous community used or be used as a variable for the purposes of analysis?

Yes/No

2. Community Engagement

2.1 If you answered "Yes" to questions 1.1, 1.2, 1.3 or 1.4, have you initiated or do you intend to initiate an engagement process with the Indigenous collective, community or communities for this study?

Yes/No

2.2 If you answered "Yes" to question 2.1, describe the process that you have followed or will follow with respect to community engagement. Include any documentation of

consultations (*i.e., formal research agreement, letter of approval, PIC, email communications, etc.*) and the role or position of those consulted, including their names if appropriate:

The research was based on agreement with the indigenous community. The methodology used was participatory and thus there was consent from individual participants and the leadership to participate

3. No Community Consultation or Engagement

If you answered "No" to question 2.1, briefly describe why community engagement will not be sought and how you can conduct a study that respects Aboriginal/ Indigenous communities and participants in the absence of community engagement.

Name of Principal Researcher: Dr. Caxton Gitonga Kaua
Affiliation of Principal Researcher: Africa Research and Impact Network



Declaration: Submitting this note by email to any journal published by The Grassroots Institute is your confirmation that the information declared above is correct and devoid of any manipulation.

INFORMATION AND CONSENT FORM FROM RESPONDENTS

(Non-Indigenous or Indigenous Respondents)

This form was translated into local language for the respondents

Pastoralists' Socioecological Trends

Principal Researcher:

Dr. Caxton Gitonga Kaua

Africa Research and Impact Network, Nairobi, Kenya

Research Supervisor:

A) INFORMATION TO PARTICIPANTS

1. Objectives of the research

This study is aimed to analyze the socioecological trends of pastoral systems with a focus on Laikipia County, Kenya. The study analyzed how pastoral systems have evolved across demographic, social, economic, environmental and economic dimensions.

2. Participation in research

The researcher will ask you several pertinent questions. This interview will be recorded in written form and should last about 50-60 minutes. The location and timing of the interview will be determined by you, depending on your availability and convenience.

3. Risks and disadvantages

There is no particular risk involved in this project. You may, however, refuse to answer any question at any time or even terminate the interview.

4. Advantages and benefits

You will receive intangible benefits even if you refuse to answer some questions or decide to terminate the interview. You will also contribute to a better understanding of the good causes for pastoralist communities of the Laikipia County.

5. Confidentiality

Personal information you give us will be kept confidential. No information identifying you in any way will be published. In addition, each participant in the research will be assigned a code and only the researcher will know your identity.

6. Right of withdrawal

Your participation in this project is entirely voluntary and you can at any time withdraw from the research on simple verbal notice and without having to justify your decision, without consequence to you. If you decide to opt out of the research, please contact the researcher at the telephone number or email listed below. At your request, all information concerning you can also be destroyed. However, after the outbreak of the publishing process, it is impossible to destroy the analyses and results on the data collected.

B) CONSENT

Declaration of the participant

- ⇒ I understand that I can take some time to think before agreeing or not to participate in the research.
- ⇒ I can ask the research team questions and ask for satisfactory answers.
- ⇒ I understand that by participating in this research project, I do not relinquish any of my rights, including my right to terminate the interview at any time.
- ⇒ I have read this information and consent form and agree to participate in the research project.
- ⇒ I agree that the interviews be recorded in written form by the researcher: Yes () No ()

Signature of the participant : _____ Date : _____ 10 Dec 2022 _____

Surname : _____ First name : _____

Researcher engagement

I explained to the participant the conditions for participation in the research project. I answered to the best of my knowledge the questions asked and I made sure of the participant's understanding. I, along with the research team, agree to abide by what was agreed to in this information and consent form.



Signature of the researcher :

Date : 10 Dec 2022

Surname: *Kaua*

First name: *Caxton*

- ⇒ Should you have any questions regarding this study, or to withdraw from the research, please contact Mr. Caxton GitongaKaua or by e-mail at caxtonk2008@gmail.com
- ⇒ If you have any concerns about your rights or about the responsibilities of researchers concerning your participation in this project, you can contact the Director, Research and Impact Network, Nairobi, Kenya, Tel: +254746130873 Email: info@arin-africa.org